WHAT IS PHYSICAL LIFE

W. HANNA THOMSON

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ITS ORIGIN AND NATURE

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PREFACE

DISCUSSION about the origin and development of life upon this globe cannot now be discountenanced nor prevented. It is a subject too interesting and too important to be ignored by any intelligent person. Being at present actually the leading subject of scientific investigation, the general reader should become acquainted at least with the principles of that investigation, enough to enable him to avoid many prevalent misconceptions about the conclusions so far reached.

Previous to our own age, views on this question were based either on speculation or on tradition. They now claim to be based entirely on observation. But ob-

servation, when yet incomplete, may give rise to as many theories as ever pure speculation did. The whole subject indeed is relatively so new that only those who have been investigating it know how vast its field is, and how much of that field is still unexplored. It is unpleasant for a science to admit that about its main points it has little but hypotheses to offer, but for the present that is the most biology can do. Nor is this at all to its discredit, for the growth of any science requires time, and none more so than this particular and great science.

This book, however, is written to show that enough has been demonstrated already to prove that the hypothesis of earthly life ever having had a spontaneous, or mechanical, or physico-chemical origin, is wholly untenable. This conclusion, though supported also by other strong evidence, is the only deduction permissible

from the fact that life existed on this globe for untold millions of years in very specific and hereditary forms, before there appeared on earth a single living thing which could be visible to the naked eye. During this period some of these forms materially altered the earth's surface. In this vast living world of microscopic forms, therefore, was the *origin of life here.* This inference is further borne out by the significant fact that every visible living thing now, however gigantic in size, yet begins with only a single microscopic cell to its physical being, and likewise must every descendant from it so begin. Without a microbic beginning no form of life, is a universal law. But the ancient and permanently unicellular living forms still constitute the largest and most powerful division of the living kingdom, with moreover such important relations to all visible forms that we ourselves can postpone the

natural ending of our earthly existence only by understanding the laws which govern this original domain of physical life.

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CHAPTER I

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THE DARWINIAN AND OTHER THEORIES ABOUT PHYSICAL LIFE

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No intelligent person can fail to be interested in the great question, what makes physical matter living matter? This question has been the oldest, and still remains the latest topic of scientific discussion. It is well, therefore, to recognize at the outset why no agreement has been reached on the subject. It is chiefly because living matter constantly ceases to be so. If it were not for death, we could study life as we would any other phenomenon. But wholly different from any other great reality in this world, life is and is not, leaving us quite unable to say what that is which departs with death. Matter may change from one form to another

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until it may become invisible; but every part of it can be then experimentally accounted for. Not so with life. It goes at death no one knows where, and never does it return to that matter which it once made living, whether it be in a flower, in an insect, or in a man.

In the face of this mystery one natural conclusion was that life is like nothing else, and coming originally from its Creator, it entered the various living forms on earth as they were ready made for it. Milton in his *Paradise Lost* describes the process itself of this making as quite parallel to the hand-made productions of us human beings, and this conception of the word "create" still holds its place in the common term creatures, applied to animals as the most living of things. This unique event of the creation of living forms was readily supposed to have had a historical date not very far back in time.

But the modern science of geology made this explanation quite out of the question, at least so far as its conception of the term, to create, is concerned. Geology presents a very readable narrative of past life on this globe, based on records so safely preserved in rocky strata, that whether they tell of great trees, of giant animals, of small insects, or of delicate ferns, the complete life history of each can now be given.

This story summed up proves to a certainty that the history of life on this earth is a very long one, with many chapters, each chapter abounding with illustrations picturing a great variety of forms both vegetable and animal. At first it was supposed that these forms differed so from chapter to chapter that most of them were altogether new when they first appeared. It is now, however, generally admitted that this is not so. Instead a continuous line of de-

scent links the whole succession of living forms from the latest back to the earliest, until we cannot but infer that no form of earthly life ever came into existence without its own living parentage. This deduction is rendered probable by the fact that the former puzzles of tracing any community of origin between widely separated living forms existing at present on the earth, is being gradually solved by the discovery of geological records showing that one form after the other formerly existed where their nearest of kin now no longer live. In other words, geology records not only great mutations but also great migrations of both plants and animals.

But the chief interest of this geological history of earthly life lies in its demonstrations of a prolonged and gradual course of development from earlier simpler to later more specialized forms. Now we

are just as free to investigate the causes of this progressive development as we are to follow the history of this earth as a planet. Without doubt natural laws have presided as much over the one as over the other, and Science is quite within her legitimate province in her investigation of either of these sets of phenomena.

As this progressive development could not have been spontaneous, a number of theories have been advanced from time to time to explain its cause or causes. The theory, however, which has attracted by far the most attention was that promulgated by Charles Darwin in his great work, *The Origin of Species,* published in 1858. Because of its great merits of simplicity and apparent adequacy to explain the problem, supported as that explanation was by a striking array of scientific evidence, it was hailed with much enthusiasm as all that could be

asked for. An illustration is found in the following passage from the book, *In Starry Realms,* by Sir Robert Ball, an eminent astronomer, published afterwards, which concludes with this estimate of the Darwinian theory: "I would liken," he says, "the voyage of the *Beagle* (during which Darwin began his studies) to the immortal voyage of Columbus. In each case a new world was discovered. . . . Astronomers were the first evolutionists. They had sketched out a majestic scheme of evolution for the whole system, and now they are rejoicing to find that the great doctrine of Evolution has received an extension to the whole domain of organic life by the splendid genius of Darwin." After describing how the astronomer went about completing his evolution of worlds, he proceeds: "His work being done, he now hands over the continuance of the history to the biolo-

gist. The lifeless earth is the canvas on which has been drawn the noblest picture that modern science has produced. It is Darwin who has drawn this picture. He has taken up the history of the earth at the point where the astronomer left it and he has made discoveries which have influenced thought and opinion more than any other discoveries that have been made for centuries. . . . The method Darwin adopts is of the most captivating simplicity. When the history of science in our century comes to be written, the interest will culminate in the supreme discovery of Natural Selection."

The enthusiasm of Sir Robert Ball then leads him on to extend the principle of Darwinism, which as usual he loosely speaks of as synonomous with evolution, to surmising that very little is needed now to suppose that life had a spontaneous origin from matter. "Can it be possible that

the wondrous and complex phenomena known as life are purely material? Unusual, indeed, must be the circumstances which will have brought about such a combination of atoms as to form the first organic being. But great events are always unusual. It is not necessary to suppose that such an event as the formation of an organized being shall have occurred often. If in the whole course of millions of years past it has once happened, whether on land or in the depths of the ocean, that a group of atoms, few or many, have been so segregated as to have the power of assimilating outside material, and the power of producing other groups more or less similar to themselves, we have but little more to demand of the theory of Spontaneous Generation. The more we study the nature of matter, the less improbable will it seem that organic beings should have so originated."

As a commentary upon these exultant words of an astronomer, written in 1892, we would merely cite a sentence from a communication by the eminent botanist, Sir Thistleton Dyer, F.R.S., to the leading English scientific journal *Nature,* July 30, 1896. "The Darwinian theory of Organic Evolution seems hardly to have a convinced supporter left [in England] except Mr. Alfred R. Wallace and myself!" (Dyer). This communication was written after a prolonged discussion just held at the Linnean Society, in which many of the leading English biologists took part, with the result of revealing a state of opinion among those gentlemen which Mr. Dyer pathetically laments. Of course Mr. Dyer does not mean that there are no Darwinians surviving in England but Mr. Wallace and himself. Instead of that, the public highways especially are crowded with individuals with Sir Robert

Ball's notions. What Mr. Dyer means is that there are now only two identifiable specimens remaining of the kind among biologists. Had Sir Robert Ball but a moderate acquaintance with biology, he would have known that even in 1892 there was a rapidly spreading conviction among the only kind of men who have a claim to speak authoritatively on the subject, that the Darwinian theory is hopelessly inadequate to explain the course of development of living forms, for so thoroughgoing an evolutionist as Professor Karl Pearson, F.R.S., says, "It can explain no more than fringes of evolution," and that every year even these fringes are being materially curtailed. Moreover, that Mr. Ball had as little right to leave his telescope and deliver himself, as above cited, about spontaneous generation, as a biologist would have to tell what he thought about the planet Venus after

trying to observe it with a one-twelfth inch oil immersion lens of his microscope, is sufficiently illustrated by the words on this subject of one of the greatest biologists of the age, Professor Carl Wilhelm von Nägeli of Munich, who says, "That the distance which separates man from the lowest bacterium is far less than the distance between the lowest bacterium and inorganic matter!" Then as to the "supreme discovery of Natural Selection" accounting for the origin of species, Professor Nägeli remarks, that Natural Selection might have been of use to prune some leaves from the biological tree, but that it was totally unable to give origin to the smallest twig thereof.

The Darwinian theory, as is well known, first postulates an inherent tendency to spontaneous variation in all directions, in living organisms, plant or animal, and secondly, that those variations

will survive which prove advantageous to the organism in the struggle for existence with either competing living forms or with the conditions of its environment. All changes, therefore, which finally lead to distinct species come simply by the elimination of the less adapted by the better adapted to their surroundings. This latter proposition, or the survival of the fittest by Natural Selection, of course assumes that an organism, once acquiring an advantage, would transmit it to its descendants. Natural Selection would be of no avail in producing varieties, and their species, unless inheritance comes in to so establish a variation. The transmission of advantageous characters, therefore, is one of the great original pillars of the Darwinian edifice.

But it should be noted here that biology, or the science of life, is no simple thing by any means. Instead its domain is so vast

and varied that by an unavoidable necessity its cultivation can be carried on only by great numbers of hard-working specialists, such as zoölogists, naturalists, botanists, entomologists, embryologists, paleontologists, anatomists, physiologists, pathologists, physicians, etc., every one of whom has something important to say about the development and laws of life. On any other highly complex subject expert opinion is most sensibly asked, but in biology only such opinion is worth anything. And it is but the simple truth to say that at present the opinion of such experts in all the different fields of biological research is preponderately adverse to the claims of the Darwinian theory, and is steadily growing more so. A few citations, out of many more which our limits forbid our quoting, from the writings of leading European and American biologists will suffice to make this plain.

Professor Wilhelm Roux of the University of Jena is one of the foremost original investigators in this field in Europe. In his latest work of some two thousand pages, entitled *Mechanism and Biology,* before advancing his own remarkable views, he first labors to demolish the Darwinian theory as one would clear the ground of tree stumps before building a house, which he does by showing the extreme difficulty of accounting by simple natural selection for the innumerable adaptations, carried out into the finest detail, which are met with in all the organs of the vertebrate body. We cannot go over the whole case which Roux makes out, but will only quote this sentence from a review of his book by Mr. E. W. McBride, a leading member of the younger school of English naturalists: "It must be admitted that Professor Roux has brought together a most power-

ful case against the doctrine of the all-sufficiency of natural selection, and we feel sure that his arguments will awaken a sympathetic chord in the minds of many, if not most, zoölogists, among whom there is a general feeling that we want more than natural selection."

Professor H. F. Osborn of Columbia University, in an elaborate paper which attracted wide attention both in this country and in Europe, read before the American Association of Science, August, 1894, on the " Rise of Mammalia," sums up with the conclusion that " The point is that a certain trend of development is found in each species leading to an adaptive or to an inadaptive final issue, but extinction, or survival of the fittest, seems to exert little influence *en route.*"

No name stands higher among working biologists than that of Professor Oscar Hertwig of Berlin. But in his ponderous

volume on *Epigenesis* he does not conceal his contempt for the Darwinian theory by Natural Selection, and similar repudiations of it are reported with each succeeding year. Thus Professor Von Hartmann says, " that in the first decade of the twentieth century it has become apparent that the days of Darwinism are numbered. Among its latest opponents, besides many others, are such savants as Eimer, Professor of Zoölogy in the University of Tübingen; Gustave Wolff; De Vries, Professor of Botany in the University of Amsterdam; Hooche, and Fleischmann. Professor Fleischmann of the University of Erlangen maintains that the Darwinian theory of descent has not a single fact to confirm it in the realm of Nature, that it is not the result of scientific research but purely the product of the imagination." Professor G. Henslow, F.R.S.,* says:

* *XIX Century and After Magazine,* November, 1906, p. 795.

"It is now half a century since Darwin's work on the *Origin of Species* by Natural Descent has been published. Up to the present day it is an undisputable fact that not a single variety or species of any wild animal or plant has ever been proved to have had its origin by means of natural selection."

The eminent Russian botanist, H. Korchinsky, labors to prove that natural selection, to use an American phrase, does not select worth a cent, but if anything prevents the formation of new species. His five propositions, which we have no room to quote, by which he claims to show that natural selection has no real power to select, contrast greatly with the expressions of some writers who imagine that natural selection has been operating through infinite time in the past. But as the remains of multicellular living forms occur first only in the lower Cambrian

rocks, from that date to this period is but a speck in infinite time. But granting this restricted period, numbers of biologists maintain that the supposed powers of environment are more destructive than selective, or, as Dr. Morier says, the proper term for them is natural Extermination rather than natural Selection. Among the countless copepods which a whale sifts for food out of sea water, what difference does it make if some of the copepods had become more developed than others or not; they all would have to go together down the whale's throat.

Among American biologists the opponents of the theory of natural selection are no less numerous. As Professor V. L. Kellogg * of the Leland Stanford University of California, in his elaborate work

* Professor Kellogg's book affords one of the best reviews that is published on this subject, and contains impartially the statements of both those who favor and who oppose the Darwinian Theory among biologists.

entitled *Darwinism To-day,* says, page 90: "Men using, or rather testing, these theories every day in their work in field and laboratory, find selection insufficient to explain the conditions that their observation and experiments reveal to them. These men are students in all the lines of biological work, whether zoölogists, botanists, paleontologists or animal and plant breeders. From all these lines of work come increasing complaints; selection cannot explain for me what I see to exist. From some the cry is more bitter; selection is a delusion and false guide. I reject it utterly. For me [Kellogg] I repeat this is an objection of much significance and importance that the biological experimentalists, the students of variation and heredity, of life mechanics, are finding the rigid theory of selection's control of all processes and phenomena a rack on which they will no longer be bound."

But we need not weary the reader with more of such citations, or with long lists of the names of authorities, which, however well known to students of biological literature, to the general reader would convey as little information as they would to a Chinaman. All we would remark is that these criticisms of Darwinism do not come from *amateurs,* but from qualified experts. It is to be regretted that some of them, especially in Germany, show that there can be as acrid an odium scientificum as ever there was an odium theologicum, for one professor intimates that there can be no Darwinian except he be afflicted with a congenital inability to think clearly, while another says that a believer in natural selection must have softening of the brain.

The chief credit which historically will attach to the name of Charles Darwin is that more than any one else in our times

he established the conviction among biologists that the processes of life are as completely subject to natural laws as are all other processes in the world. He also possessed in an eminent degree a fair and open mind towards opponents, while he pursued his course of observation and experiment in the spirit of an ideal scientific investigator. Full appreciation of these personal traits was widely expressed at the recent celebration of the centenary of his birth by the leading biologists of Europe. At a like gathering in America, the chairman,* Professor H. F. Osborn, while remarking that "there is no denying that there is to-day a wide reaction against the central feature of Darwin's thought," yet eloquently sets forth the lasting honor which will attach to Darwin's name in the world of science.

* *Popular Science Monthly*, Darwin Number, April, 1909.

Certain great discoveries, however, about the mechanism of life, which every one should know and which should be taught in our schools, have done much towards modifying the views of biologists on the Darwinian theory.

The physical basis of life is a sticky substance called protoplasm, and when its relation to living growth was first discerned its spontaneous generation seemed as possible as it did to Sir Robert Ball. This conception, however, was very temporary, so that Huxley always winced in after life at the mention of Bathybius, a term which he invented for an imaginary ooze lining the ocean bottom and which he fancied might generate the first beginnings of protoplasm. But on investigating the protoplasm in cells, instead of being a jelly-like thing of simple construction, it proved to be the most complex substance in the world, of such infinite complexity

that biologists are all equally lost in trying to imagine it. Because, it turns out, that all forms of life, no matter how large they may grow afterwards, have to begin as specks of protoplasm visible only by high-power microscopes. There is no help for it: without a microbic beginning no form of life, great or small, is a universal law. The sulphur bottom whale of the Pacific, though he may bulk afterwards and weigh as much as 3000 men, yet first starts in his one microscopic primordial cell just as a towering oak also does. All biological investigation, therefore, had to be shifted from adult living forms to their first beginnings, when only a microscope can see them, with the result of a corresponding shrinkage in the belief of many Darwinians. When sheep, dogs, fowls, and such like familiar creatures were the objects of study, it was comparatively easy to trace the origins of their many varia-

tions, and to illustrate these by the products of selection by human breeders. But when the search for the secret of all physical life led first to a microscopic cell, and then to a much smaller body in the cell called its nucleus, and then to far minuter things in the nucleus called the chromatin rods, the whole question of natural selection, along with many other like questions, seemed in danger of being lost both to sight and to conception.

But the original Darwinians were soon to experience another severe strain. Professor August Weismann, the eminent biologist of the University of Freiburg, announced as the result of his observations that no physical change occurring in the body of either a plant or animal during its lifetime can be transmitted to its descendants.

To an ordinary mind this assertion seems ruinous to the whole Darwinian

edifice, which was first based on the transmission to offspring of advantageous variations to help them in their struggle for existence. Herbert Spencer at once took the alarm at Weismann's declaration and exclaimed that without the transmission of acquired characters there could be no evolution, and like expressions came from others and continued down to Sir Francis Darwin, son of Charles Darwin, who in his inaugural address as president of the British Association of Science, at its meeting in Dublin last year, declared that true Darwinism must wage a war to the knife against this dictum of Weismann. The weight of opinion, however, among biologists seems at present to favor this contention of Weismann, that acquired characters are not transmitted, but when he proceeds to show how he is as good a Darwinian as anybody by his purely speculative views of what comes out of the chro-

matin rods in the nucleus, he falls foul of an equally eminent biologist, Oscar Hertwig, who complains that Weismann leads us into an invisible world, in which there is no foothold for research, and with no foundation of fact.

This is only a sample of the interchange of personal compliments which has been going on between different authorities in biology for the last twenty years. The only agreement is that every one believes in evolution, but as to the process of evolution there is an all-round disagreement, with no prospect of a satisfactory substitute for the Darwinian theory in sight.

The only alternative theories which have attracted much notice are the once celebrated Lamarckian theory, and the more modern theory of Orthogenesis. Lamarckianism, in distinction from the natural selection of Darwinism, has Use and Disuse for its principle. By constant use

living parts grow and by disuse they atrophy. It was by constant stretching that, in the course of generations the giraffe's neck became so long, and likewise the legs and bill of the crane as it waded in the mud for its food. It was in degeneration from disuse, however, that this theory had its strongest arguments, just where the Darwinian theory is weakest, for natural selection does not account for degeneration, because nothing would select degeneration as advantageous, while the eyeless fishes in the rivers of the Mammoth Cave afford direct evidence of the loss of organs by disuse. The Lamarckian theory, therefore, is much simpler than the Darwinian, if only it were in accord with facts, which it is not, except as just stated in the case of atrophies. No native tendency to strong arms in the children of blacksmiths is discernible. Moreover, Lamarckianism depends even more than Darwinism on the

inheritance of acquired characters, and if such are not inherited, the whole theory falls.

Meanwhile, an increasing number of biologists, such as von Nägeli and the late Professor Eimer, along with the American paleontologists, Cope, Osborn, Whitman, and a number of others, have become so convinced of the inadequacy of either the Darwinian or the Lamarckian theories to explain everything that they are sure of the existence of some other important factors in the processes of evolution, though these have not yet been demonstrated. They find development often following lines which seem predetermined for it to follow before either natural selection or use could have exerted any influence. The facts on which this doctrine of predetermination, or orthogenesis as it is called, are based, are very numerous and are wholly inexplicable on any hypothesis

yet framed to account for them. The only objection which has been advanced to orthogenesis is that it is unsatisfactory to confess ignorance instead of trying to guess what we are ignorant of. But as all admit that the territory of the Unknown in biology is great, and its boundaries not even discernible, this objection does not seem sensible.

But the general reader should be on his guard now against too hasty conclusions. When he compares the confident tone with which Tyndall, in 1874, speaks of matter as eternal, and containing in it the promise and potency of life, with the words of Sir George Darwin, uttered from the same chair of president of the British Association of Science in 1905, that the elements of matter have had neither an eternal past, nor will they have an eternal future, and that the mystery of life is as impenetrable as ever, he may suppose that these learned

people know of no certainty. When in addition he hears little else than a confusing din of controversy among biologists about their theories, he may then think that this once awesome divinity of Science is after all not unlike Dickens' portentous Mrs. Harris.

But nothing could be more untrue, and therefore unjust. Neither men of science nor any one else have reason to doubt that all phenomena in Nature, including those of physical life, are due to natural causes, which science, therefore, has every right to investigate. Thus if something beyond Nature's powers is to be found anywhere it would be in the mysterious processes of cell growth in an animal body. There every different cell finds its own exactly proper place, a brain cell in the brain, a secreting cell in a gland and never in a muscle, and so on in beautiful adjustments without number, as if some great intelli-

gent agency presided over the whole ordering. But unfortunately this quasi-supernatural superintendent sometimes makes serious mistakes in his operations. What is a common wart? It is a mistake in nutrition, which if dark in color should be cut out, at least in elderly people, because no one can tell when it may turn into a well-named malignant growth. Likewise all tumors have no business to be where they are found, but particularly those dread cancers and sarcomas which kill by growing just where they please in defiance of all order or superintendence. Moreover, that some very general law of perverted nutrition is here at work, is proved by cancerous tumors occurring in all kinds of vertebrates, sheep, oxen, lions, tigers, mice, and even in fishes. But more than that we can artificially change the whole process of development by shaking or detaching the primitive layers from one an-

other, so that four frogs will grow where but one frog should, while each of these frogs, though perfect, yet will be only one-fourth the size of the ordinary frog.

Wholly different, however, in origin from cancerous growths are some tumors found in the bodies of young persons who, on their account, rarely live beyond their twentieth year. These tumors are called embryomas and are usually large, but on being examined are found to consist, as the anatomist Bland Sutton, F.R.S., describes them, of an utterly confused heap of every tissue of the body, either general or special: cartilage, bone, gland, muscle and nerve cells, besides hairs and streaks of the choroid membrane of the eye—all mixed up without a single attempt at arrangement. The explanation is that this awful thing started originally as a twin, but becoming enclosed in a bodily cavity of its fellow, the unnatural physical conditions

under which its processes of growth were placed caused it to make a sorry mess of them.

Living processes, therefore, are living enough, and nothing but life can originate them; but after that it is physical conditions which determine how they shall live.

CHAPTER II

REPRODUCTION AND HEREDITY

THE facts referred to at the close of the last chapter prove that physical or material life is regulated throughout by natural laws. These laws are just as natural as the laws of chemistry and of physics, and therefore science is properly concerned in endeavoring to discover what they are. This statement involves the conclusion that each living form, whether plant or animal, comes into being as naturally as an icicle or a waterfall. But this conclusion by no means implies that the laws of life, however natural, are the same in kind with other natural laws, such as those of chemistry or of physics, or with any conceivable modification of them. This question must be judged on its own

merits until the decision can be given according to the facts. After that is done, we contend that a consideration of the most essential elements in the existence and in the development of life shows that they are totally different from all other facts or laws and cannot possibly be derived from them. This is our contention; that life is not physico-chemical in origin or in nature we would emphasize from the outset.

When men began to think about the phenomena of Nature, their readiest explanation for everything was furnished by the consciousness of their own personality. As they acted according to their own wishes, hopes or fears, which led to their creating objects or causing events to come to pass, so they concluded that everything in nature, good and bad alike, must have a corresponding designing personality to account for it. The progress of knowl-

edge, however, dispelled all that, until it changed thunder itself from an awe-inspiring voice into only a loud noise.

But it was in accounting for the phenomena of life in Nature that this old conception lasted the longest. A sort of supernatural, vital force was imagined to be the only explanation here, and in medical science particularly this imaginary vital force arrested all progress for many centuries.

But this once crudely conceived mythical vital force remains as a name to disturb the reasoning of those who repudiate its existence. Because there is no vital force, therefore it is concluded that what things and forces we know of must account for life by supplying everything needed both for its origin and for its developments. Those things are, first, matter as a substance, and then such forces we know of that act on matter,

like light, heat, chemical affinity, electricity, etc. Hence it is maintained that because we know nothing else except the properties of matter and of force, therefore there is nothing besides these for life to come from.

We demur from this conclusion most decidedly, on the ground that the chief laws of life are now pretty well understood, and so also are the chief laws of matter and of force, and that there is no correspondence between these two whatever. Every alleged instance of living matter becoming so without the agency of previous life proves on examination to be erroneous. That all life is from life, and from nothing else, is therefore the proposition which we will discuss.

It is just here that, as it seems to us, some reputable biologists have failed to perceive the real point at issue. Because some processes of growth and of nutrition

have been experimentally proved to be profoundly affected by purely chemical agents, they appear to accept this as evidence that it is all of a piece throughout, and that further investigation will show that one after another of supposed vital phenomena will take their place in the list of physico-chemical effects until no such thing as vitality will remain.

Thus one of the hitherto most mysterious of living processes, that of the cleavage and arrangement of cells in the early stages of animal development, has been shown to be fundamentally modified by varying the chemical composition of the fluids in which the animal living cells are bathed. Professor Loeb, for example, more than confirmed similar experiments by other biologists, by demonstrating that unfertilized eggs of echinoderms, or sea urchins, when dipped in a dilute solution of magnesium chloride, then went on to

grow into complete parthenogenic forms of that animal. But these results are only in line with what was well known before, that living matter, while living, can both be affected by, and also itself give rise to every kind of physical, chemical, and electrical reactions, just as any other active agent does. Loeb had to have living embryos to experiment with, and all he did was to affect their processes of development by his solution of magnesium chloride. He could no more thus originate these animals than he could make a new egg.

But what is demanded is how to account by non-living agencies for the really essential elements in life. These, and not the accompaniments of vital activities, are the things to explain.

Thus we may well ask what physical, mechanical, chemical, electrical, or other non-living agency comes anywhere near

accounting for the really basic fact about life, namely, Reproduction, because by its processes vital reproduction excludes its being classified with anything else on earth. Thus a whale is, to be sure, a large living thing whose circulation, respiration, muscular and nervous activities illustrate many physico-chemical laws. But how can these laws account for the biological history of this animal himself? As we have already stated in the preceding chapter he began his individual existence, as every other living thing, animal or plant, large or small, has to begin, as a microscopic unicellular entity. It is the beginning of things which settles the nature of things, and when a whale begins, he is certainly a whale, though 1,500,000 such whales might be got into a space not larger than a pin's head. He also is then nothing else than a whale, and by no possibility can he grow into a fish any more than he

can grow into a bird, for whales are mammals and therefore separated by an impassable biological gulf from all fishes. Likewise an elephant, an onion, and a grasshopper all begin in single primordial cells of about the same size. Therefore, in their first microscopic cells it is all determined what they are going to be. But determined by what? By physico-chemical laws? Again, in that vanishing speck of matter constituting the unicellular whale is already settled just how all the billions of cells of his future body are to grow, how many of them there are to be, and where the bone cells, the muscle cells, the nerve cells, and all the other bodily cells are to find their places to the end of that whale's life.

But what thing in physics, or what force among forces, acts in that way whether singly or in conjunction with other things or forces? A thing may become larger by

accretion, but never by the working of complex, internal organization. No thing on earth can *grow* unless it be living. So no force or forces can shape any form of matter so that it will reproduce itself. Force and matter can make an icicle, but the icicle remains as lifeless as both the force and the matter which produced it.

But a new and portentous factor in the problem now challenges our consideration, namely, that of Heredity. Again, as already mentioned, in the wonderful organization of this minute particle of whale matter we find that in a minuter portion of it, namely its nucleus, there is a minuter portion of this in turn, which goes by the name of the chromatin substance, and that this latter substance chiefly bears the indelible impress of all the whale's ancestry back to the first whale. On that account this whale, as he grows, will demonstrate that whales used to walk, for in his adult

state he has legs just where legs ought to be and complete in every bone thereof, but as they are now no longer usable in the ocean where he lives, they are deeply imbedded under his skin, much as an English nobleman of ancient lineage hangs up in his halls the coats of armor of his ancestors, as mementos of days long gone by, on account of rifle bullets.

But a physical atom or ion with the attribute of heredity is as unthinkable as hereditary hydrogen. We must therefore take leave here from matter and all its known properties, and restrict our attention to the familiar forces above mentioned, which play on matter according to their well ascertained laws. All admit that these forces are themselves lifeless, but it is imagined that somehow they can vivify matter and make it living. This is momentarily thinkable, but soon ceases to be so when we are really confronted with

the facts of both reproduction and heredity. No one of the known forces can reproduce itself, still less can it go through the cycles of successive generations, any more than matter itself can. A hereditary unit of heat is as absurd as hereditary helium. But life without coming by hereditary descent and then going on to reproduction does not exist. Both these elements are as inseparable from life as attraction is inseparable from gravitation. But where else is there even an analogue, not only to both, but to either one of them? Vital reproduction is difficult enough, but heredity is ten-fold more so, and we have already seen to what grievous mental strain some biologists have been subjected in trying to explain how every cell and part in an adult body exists, potentially if not actively, in the single primordial cell "when as yet there were none of them," and exists there according to that

which has been transmitted to it through countless successions, not of adult bodies but of previous minute primordial cells.

Of what avail then in our discussion is it to cite the peculiar set of electrical currents in functionating nerves, or processes of growth affected by mineral salts? We might as well say that fire is caused by the smoke which generally accompanies it. In view of the infinitely complex processes fundamentally related to vital reproduction, through most ancient descent, what is the probability of experimenters being able some day to give us a formula or receipt for making life altogether *de novo?*

Meantime, the reader should now note that though in the primordial cell the matter associated with life is so near nothing, life itself, so far as its most specific properties and potentialities are concerned, exists to an unexampled degree. The microbic whale, for example, starts with more vital

elements in his microscopic body than ever he will possess afterwards, for by the time he has grown into an adult whale, and bulks as much as a brigade of men, he has spent much the greater part of his original capital stock of vital capacities. There remains in him no potential reserve of that living power to form an eye or an ear or any new tissue or organ which he had when he counted only one cell to his physical being. All he does when he is full grown is to keep what he has until it begins to decay with age.

It is true that there are still traces in him of his original capacity for making new tissues in his power of repairing bodily injuries. In animals lower in the scale of life than whales, this power of repair is sometimes strikingly illustrated. Thus, if the crystalline lens of the eye of a larval salamander be extracted, this creature soon makes a new lens out of the

posterior cells of his iris, as complete and as good as his original lens. Many biologists seem to think that this behavior of a mutilated salamander greatly deepens the mysteries of living processes. If it did not actually occur it would otherwise seem as likely as that the sides of a man's pocket should spontaneously replace the same as before a stolen pocket-book, even to the dollar bills which were in it when it was lost. But after all there is no more mystery in this salamander's making a new lens, than there is in his making his first lens. He only shows that as he did it once he can do it again by the same old power which was in his primordial cell. The only difference seems to be that animals higher in the scale than the salamander, lose, as they grow, most of that original, all-creating capacity to make new parts, until nothing is left of it except a limited capacity for repairs. But the power to

repair and that entirely to regenerate are only different degrees of that inherent living endowment residing in the first microscopic cell.

When a whale is full grown he has matter in quantity sure enough. Every action then of his nerves, especially his motor nerves, gives rise to electrical currents; every contraction of his muscles liberates heat, and all his secretory activities are accompanied with chemical changes. But do any of these elements, or all of them together, constitute his life? Not at all. What *life* he has comes from the life of his primordial cell, and from nothing else.

But the mysteries of heredity are not confined to the potentialities of the primordial cell. All cells and tissues in the body are ruled by its sway, and can never depart from it. No body cell in a walrus, from its head to its tail, can take on the pattern of a whale's body cell, because

each cell of a living body, whether it be plant or animal, has its own special pattern. The pattern of a walrus' body cells is wholly different from that of a whale's, however identical they may be in chemical composition.

Moreover, we encounter here one of those biological marvels by which science has recently revealed the fact that the *blood* is the most hereditary thing about us, for its hereditary elements override everything in the make-up of the physical animal body, whether it be the shape of the skeleton, of the lungs, of the alimentary canal, or of the skin. It even overrides ancestral habits as to the great Food Question—Darwin's chief creator, which works by the strife in Nature about how to eat or keep from being eaten. This discovery of the hereditariness of the blood came about in this way.

Some of the most recondite investiga-

tions in the history of medicine have been about the mechanism of Immunity, or why a single attack of certain infectious diseases renders a person immune from a second attack. It was through these investigations that some valuable antitoxins were discovered in the immunized blood serum, which raise hopes that we may yet find the antitoxins for the worst forms of our deadly infections, just as an antivenom has been found for the cobra's poison, and another for that of the rattlesnake. But each of these antitoxins is specific in that it does not afford any protection except just against its own poison. This led Professor Wasserman of Vienna to investigate whether the blood of each kind of animal did not contain some ingredients which would be specific to that animal, that is, not to be found in any other animal, a fact which, if found, might be of use in medico-legal cases.

His results made this so probable that Professor Geo. H. F. Nuttall, F.R.S., of the University of Cambridge took the subject up, and has so extended its application that a single drop of blood from any animal now suffices not only to show by its peculiar chemical reactions what animal it comes from, but also how nearly related, or the opposite, an animal is by his blood to other animals. It begins, therefore, to look as if the whole classifications of zoölogy may have to be rearranged according to these blood tests. Thus, a drop of the blood of a walrus shows no relation with a drop of whale's blood, or of the blood of any other cetacean, such as seals or porpoises, which, like the walrus, are mammals that have taken to the sea. Instead of that, the blood of the walrus immediately reacts with the blood of horses, asses, and zebras, thus proving that he is an equine that no longer

crops grass, but goes where he can live on an exclusively fish diet. Likewise, the hippopotamus is shown to be a modified pig.

Where blood relationship exists, but is distant, these reactions are proportionately faint, but where no reactions occur there is no relationship at all. Thus, geology indicates that birds are descended from reptiles, and oddly enough, the blood of a bird shows a distinct, though very faint, reaction with the blood of a snake, but none whatever with that of the winged bat or the flying squirrel, for these are mammals.

On the other hand, the marsupials, once such a great family, but now reduced to the kangaroo, the opossum, and a small creature in South America, have now not a single blood relation left. As to man, he has no relationship to monkeys, but the blood of anthropoid apes shows a very

faint reaction with his. Meantime, all the races of man are unmistakably of one blood, whatever their color or abode.

Heredity, therefore, is inseparable from living matter, whether it be in man, in animals, or in trees, or whether in the smallest microscopic particle thereof. In one sense it and physical life are one, for no matter can be living without it. It is absolutely unique, for what else is hereditary? Certainly nothing physico-chemical that we know of. It doubtless has its own laws as everything else has. But laws explain only sequences, and never origins. At every turn we find mysteries connected with heredity which no known law explains. But so accustomed do we become to associate heredity directly with parent and child, linking the one to the other, that we do not know what to say about the worker bee, which for the past hundreds of thousands of years never had a working

father nor a working mother to impart to it that wonderful skill which it shows in constructing the cells of its honeycomb. But bees abound in unaccountable inheritances. Darwin's survival of the fittest, however, may contribute a ray of light on one of their constitutional laws. With a do-nothing male, after his case has been duly considered, two of his spinster sisters take him outside and put him to death, thus ridding their community of such a make-weight. We have not yet reached that utilitarian stage of development, but Darwin thinks that if we only had the useful moral standards of bees we would see nothing wrong in such a performance.

But bees are not the only hymenoptera which illustrate the puzzles of heredity.

In one particular species of wasps, the Eumenes, the female makes a most peculiar provision for the nourishment of the offspring which she will never herself live

to see, and as the same was thus provided by her mother who likewise died before her, she could not have learned this remarkable proceeding from her. This wasp first makes a secure papier maché-like box, as it may be called, and having finished that, she then goes on a hunt for the proper spiders, which she stings one by one, and then deposits in the end of the box. This sting does not kill the spiders, but only benumbs them, so that they remain hypnotized, as it were, awaiting their doom from the larval wasp when it hatches out of the egg which the wasp lays only after enough spiders have been deposited for the hatched larva to feed upon. Here this wasp shows an accurate knowledge of the nervous anatomy of spiders, as she stings only that ganglion which does not include the respiratory centres, for that would be fatal. As the adult wasp does not often feed upon spi-

ders herself, this benevolent arrangement is for the purpose of providing proper baby food for her young. But how in the world did she inherit this most complex way of doing things? It would not have done at all to kill the spiders with her sting, for this larval wasp must have only living meat, and not even meat kept in cold storage.

But the genus hymenoptera includes not only bees, wasps, hornets, and other insects, but also the ants, and we might fill pages with the curious hereditary habits of the ants alone, which are as inexplicable as any of the rest. To ascribe them to Instinct is simply to get behind the most expansive of all words for veiling blank ignorance.

CHAPTER III

THE UNICELLULAR MICRO-ORGANISMS THE OLDEST AND STILL THE LARGEST DIVISION OF THE LIVING KINGDOM

After the discussion in the previous chapter of the subjects of Reproduction and Heredity, we now can properly allude to the subject of Abiogenesis, which means either the spontaneous or artificial generation of life from non-living sources. Some experimenters have seemed to think that by bringing together in proper conditions the physical components of living things and subjecting them to the action of various forces, life might be generated anew much as spontaneous combustion sometimes occurs in collections of inflammable materials. This apparently not improbable surmise has led to speculations about

abiogenesis from ancient times, because *a priori* there seemed to be no logical reason for denying that as physical life must have had a beginning once on this earth, this might happen again. This conclusion is all the more natural for those who maintain the doctrine of the physico-chemical origin of life, because all the physical and chemical elements are yet with us as effective as ever. Repeated attempts, therefore, have been made to produce life artificially, and occasionally we hear of such experiments being apparently successful. But to be living, such an artificial specimen must be capable of a cell formation which then goes on to reproduce itself by cell division or mitosis, and then continues to do so independently for successive generations. If it can do nothing of the kind, then this supposed living substance is a delusion.

But it would seem as if this subject

could be best investigated in that great division of the living kingdom which is composed wholly of unicellular organisms, or living things which have but one cell to their physical being. This apparently would make our problem quite simple, for as there are no complex relations with other things to interfere, we have but one living thing before us which lives, reproduces itself, and dies the same small, single, unicellular entity throughout. Moreover, these things are universally rated as the lowest and simplest forms of life and therefore possibly not far removed from the inorganic kingdom.

But the more we learn about the unicellular world of life, the more unthinkable abiogenesis becomes.

In the first place, unicellular forms differ widely, and yet so definitely between themselves that they can be divided into four distinct genera. First come the

Protozoa, which are of animal nature. Second, the Bacteria, which have vegetable affinities. Third, the unicellular Algæ, and fourth, the Foraminifera.

Among bacteria there is no mixture or crossing to anything like the degree to be found among visible plants and animals, but each species has its own specific characters, making it as unlike other bacteria as any two living things can be, for example, a horse and a camel. A typhoid bacillus can by no possibility become an influenza bacillus, nor that in turn a leprosy bacillus. Each species presents a multitude of its own distinguishing features, as the following facts demonstrate.

Thus, though it may seem odd to speak of size as a feature among microscopic living things, yet they actually do vary in this respect as much as visible forms do. The bacillus of anthrax is as much larger than an influenza bacillus as a cat is larger than

a mouse. But the influenza organism is a magnate compared with the yellow fever agent, for this is so small that not one of our wonderful microscopes has yet caught sight of it, and that this is due to its almost inconceivable minuteness is shown by its passing readily through the pores of a Berkeley porcelain filter which stop the larger bodied organisms of smallpox.

But the difference in size is a minor matter compared with the great contrasts in vital properties between the various species of these unicellular forms. A tubercle bacillus is in every respect wholly unlike the bacillus of the bubonic plague. The first generally takes months or years before it completes its work, while the other is never chronic, but runs its course in a few days. They differ as much also in their chemical composition and in the chemical accompaniments of their growth on non-living media. Again, some bacilli

are non-motile, or can scarcely be said to move at all, but the cholera vibrio squirms so incessantly that no snapshot of it can be taken, all its micro-photographs being blurred because it will not keep still. Meantime, each of these agents kills its victims in wholly dissimilar ways. Some of them will attack the same person only once, while others find a previous attack makes another all the easier. And so we might go on enumerating many other absolute and fixed characteristics which distinguish these unicellular forms of life from one another, but enough has already been adduced to establish the fact that no forms of life anywhere are so individual and specific in their kinds as the unicellular forms.

In this respect they markedly differ from all other plants and animals. In the unicellular forms but few and relatively incomplete variations occur, such as between

the avian, the bovine, and the human varieties of tubercle bacilli. But these are so little removed from one another that their title to distinct species is still doubtful. The same may be said of the colon group, to which the typhoid bacillus belongs. More can be said of the changes in the variola agent in vaccinia by change in its soil or medium of growth. When changes are artificially produced in them by altering the medium or soil in which they grow, no new species is thus formed, for they either die out or revert to their original characters so soon as their original native conditions are restored. Hence, no permanent and general modification takes place in them, as in visible plant forms like the botanical family of the solanaceæ, for example, which includes such divers forms as the potato, the eggplant, the thorn apple or stinkweed growing about our barnyards, the hyoscyamus, and the belladonna

or deadly nightshade vine. That excellent botanist, however, the potato bug, if potato vines give out, at once turns to what eggplants he can find, and those failing, he eats the stinkweed, and lastly the belladonna vines.

But as to unchangeableness we may say that empires have risen and fallen, great races of man have come and gone, yet the tubercle bacillus causes in us the same tuberculosis which Hippocrates so well described, two thousand three hundred years ago, and some think that Ebers' Egyptian papyrus alludes to tuberculous ulcers thirteen hundred years before Hippocrates. Had Hippocrates only possessed a properly equipped laboratory he might then have identified the tubercle bacillus and distinguished it from other bacilli, because it takes a characteristic stain with methylene blue made faintly alkaline with caustic potash, and it contains more fat than any

other bacillus. . . . Likewise the bacillus of leprosy has come down the same through the ages, from the early dynasties of Egypt, and in the Book of Leviticus it is wisely ordered to burn the plaster of a leper's house. In the sixth chapter of First Samuel, a severe epidemic is narrated as having occurred among the Philistines, which must have been the bubonic plague, for the Philistines are said to have made, in order to appease their gods, golden images of buboes and of rats; for the term mice, in the English version, represents a Hebrew word which included both mice and rats. It was not till more than three thousand years had passed that the Japanese bacteriologist, Kitasato, demonstrated that the plague is conveyed to human beings by fleas which have bitten rats sick with the plague. Smallpox was described by Chinese physicians more than a thousand years ago,

and this infection continues its same nefarious ways till now. Yellow fever remains the same yellow fever in every respect as the first historic description given of it.

This mention of smallpox and yellow fever justifies our alluding to the contrasts between the living agents of these two infections, if only further to emphasize the specific differences which distinguish them from one another. The yellow fever germ can go nowhere except as his mosquito nurse carries him. Moreover, he cannot endure the slightest touch of frost, though that may not be fatal to his mosquito. He has never been known to ascend mountains. The smallpox agent, on the other hand, can be carried by anything, as was illustrated on one occasion by an official visit of mine to a smallpox hospital, accompanied by a confrère. There was but one smallpox patient in the building, and we were careful not to come near enough to

touch him. We then proceeded directly to the steamboat waiting for us on the East River, which at that time was filled with floes of ice, and we paced the deck in a biting cold wind, hoping thereby to disinfect our clothes. After a two miles' trip we landed, when my colleague took his carriage to visit a woman whom he had attended a few days before, in confinement, with a pair of twins. Twelve days afterwards both infants broke out with smallpox, to the consternation of the mother, and the feigned astonishment of my colleague.

We may remark in passing that the infinitesimal size of the agent of yellow fever raises the question how much of that substance called matter is necessary to make a powerful living thing. It is hard to imagine anything more effective than it in the work it does, which may destroy in a few hours a strong man in the prime

of life, not because it is a chemical poison, but because it is a living growth belonging to an infection historically known for centuries. We cannot expect therefore that experimenters will soon be able artificially to make life, when not only the yellow fever agent, but those of hydrophobia, rinderpest, and a number of other infections of cattle, are not large enough to be seen by any microscope, and hence are beyond handling.

We have shown in the previous chapter that Reproduction and Heredity are the two fundamental factors in all physical life, and how impossible it is to find any analogue to them outside the domain of life. But much the most striking illustrations of both great reproductive powers and of heredity are shown, for example, in the case of the tubercle bacillus. His term of life, instead of being, as with us, threescore years and ten, is only from twenty

to thirty minutes, but he can have 17,000,000 descendants in twenty-four hours.* Now, estimating the life only of an elderly tubercle bacillus at thirty minutes, and then calculating how many generations he goes through in the three thousand years since we have made his acquaintance, he has traced his descent through 5,450,000 generations, without once deviating from the venerable type with which he began. This only illustrates afresh what a complex and absolutely unique thing life is. When lately a new star suddenly flashed in the heavens and after a time faded away, astronomers agreed that the origin of this latest "Nova" was from the collision of separate stars or of streams of meteorites, which, judging by the rate at which light travels, probably took place while Solomon's Temple was in building. But the problem of the origin of a star is simple

* Muir and Ritchie, *Manual of Bacteriology*, p. 6.

enough compared with that of one bacterium.

A fact which overshadows all others about unicellular forms was naturally not suspected until after microscopes were made. But it is now revealed that this once invisible world is much the largest division of the living kingdom, exceeding in actual bulk all visible plants and animals put together. To illustrate their relative extent we might liken the unicellular kingdom of life to a lake, that of all visible plants to a pond, and that of all animals to a pool. This is because all visible plants and animals are necessarily local—even a tiny blade of grass is not found everywhere—while among the unicellular forms the bacteria alone may be said to be everywhere, on everything and in everything, whether in earth, water, or air. Nor, as we shall see, are they there in vain. Simply to illustrate this vitally important

fact, we may dwell on the scene at a surgeon's operating table in one of our modern hospitals.

The surgeon himself and all his staff are dressed like the old priests of Solomon's Temple, wearing white caps and gowns, with the nurses standing around like priestesses all in spotless white, while every one about the table has gone through as many ablutions as befits the occasion of a bloody sacrifice under the auspices of the immaculate Goddess of Cleanliness. A minute and elaborate ritual has been observed of sterilizing everything—towels, threads, needles, forceps, instruments, and what not, while the floor itself is made of glass or glazed tiles, rather than of wood. The surgeon himself does not venture to cut the victim till he has put on his sterilized gloves, because he cannot possibly clean his own fingers enough. Should any onlooker take his hand out of his pocket to

reach for the gaping wound he would be ejected instanter for spoiling the whole performance with his defiling touch.

Every item and detail in the foregoing description simply illustrates how nothing escapes being covered with these unicellular micro-organisms.

But instead of associating bacteria, as many do, with nothing but surgery or disease, we cannot but infer that such a preponderating realm of life as that of the micro-organisms must have a corresponding influence on the rest of the living kingdom. And so indeed it has, because, were it not for the bacteria alone, all visible plants or animals would soon cease to exist. Thus no animal or plant spontaneously decomposes after it dies, any more than do stones or rocks. Every tree which falls in a forest and the body of every beast dead in the field, would stay there but for bacteria. So soon as any living

thing gives up its life, bacteria immediately set to work upon its remains and forthwith resolve them into their original chemical elements. We can prevent all this by means which keep bacteria quiet, as when we preserve meats and vegetables with certain varieties of carbolic acid called spices, for all spices can be made artificially out of coal tar. Or we may use nature's efficient germicide, ice. Thus Nature has a great cold-storage plant in the tundras of Siberia, where the carcasses of big mammoths have lain for unnumbered centuries with their bodies so well preserved that dogs at once help themselves to them when they are dug out, and what the dogs leave the bacteria at once dispose of.

Geologists tell us that, as it is, entire strata of rocks on the earth's surface are largely made up of the skeletons of once living forms. Hence if it were not for bacteria, corpses would soon pile higher

than the Andes, and the earth would be choked with its own dead. In other words, bacteria keep life going by removing the bodies of each generation to make room for the next. Thus life here begins with microbes and ends with them. In this sense, therefore, bacteria are indispensable. We could not do without their post-mortem activities.

On the other hand, certain kinds of bacteria can be made directly beneficial to the living human world by materially increasing its food supply. Though no one would think of cultivating protozoa, yet these particular bacteria being vegetables we can raise profitable crops of them, so that some are now actually put out for sale at two dollars a small bottle.

These valuable bacteria were first discovered in little excrescences resembling warts on the rootlets of leguminous plants such as beans, peas, and clover, and were

first mistaken as signs of the plants being diseased. Further investigation proved that they were caused by colonies of bacteria which had the invaluable property of what is termed "fixing" the free nitrogen of the air. Nitrogen is a most important ingredient in all real foods, whether meat or bread, but though three-fifths of the air is composed of nitrogen, none of this vast supply can be used for food any more than the water of oceans can be used for drink. Cereals like wheat can get the nitrogen for their seeds only in the small quantity and roundabout ways afforded by decomposing animal secretions or other decaying organic matter. Hence the high price of manure per load.

Meantime bread-eaters are increasing at such a rate that according to Sir William Crookes, much too soon for comfort, there will not be manure enough, nor any other

supply of available nitrogen to feed the nations. The store of Chili saltpetre, which was originally a vast deposit of guano, is being reduced at a disquieting rate, and the plan of fixing air nitrogen by electricity, though promising, is still expensive. It is therefore welcome news to hear that these benevolent hordes of bacteria have been discovered in the very act of "fixing" nitrogen, and moreover just where it is most wanted, viz., on the rootlets of plants. Professor Hilgard of the University of California, in his treatise on *Soils,* p. 155, says that seeds sown after they have been inoculated with the purchased bacteria at the cost of two dollars an acre, can add thirty to forty dollars' worth of nitrogen more and better than the nitrogen in two tons of a chemical fertilizer such as the Chili saltpetre.

Professor Whitney of the United States Department of Agriculture goes so far

as to say that it makes but little difference what the soil is, for bacteria of the proper sort will make it fertile, and that the future of agriculture will be bound up in the application of the science of bacteriology. This science is yet in its infancy, and it is now difficult to gauge the extent of its possible advantageous developments. But already we know that trees need bacteria to prepare their food for them, and that America will be as treeless as Greece and Palestine now are, if we do not put a stop to the washing away of the bacteria-laden soil by the wholesale cutting off of our forests.

The Protozoa are, if anything, of more ancient and unvarying lineage than the bacteria. So far as we are concerned, those of them which cause disease are more to be dreaded than disease-producing bacteria. Their chief mode of entrance into the bodies of animals is by the bites of in-

sects. Thus the organism of ague or malarial fever, and the yellow fever thing, come through hypodermic injection into us by two separate varieties of mosquitoes. None of the one hundred and twenty-three remaining varieties of mosquitoes do more than sing and sting. The terribly mortal disease of Eastern India, called Kala azar, which destroys ninety-eight per cent. of those attacked, comes by the bites of bedbugs. But a special interest attaches to the fatal Sleeping Sickness of Africa, as that is due to the bite of the tsetze fly, which harbors in its mouth species of protozoa called trympanosomes. This tsetze fly is responsible not only for fearful human epidemics but for the destruction of vast numbers of cattle, and also for the deaths of some of the largest forms of wild game in Africa. It is not improbable that many of the earth's large animals now extinct may have been killed off by similar

means, for Professor A. D. Cockerell of the University of Colorado has found fossil tsetze flies in the Miocene strata of Colorado, and Professor H. F. Osborn of Columbia University has made a similar discovery in the tertiary strata of the same region. And so we will find the evidence accumulating that " the everlasting hills " themselves will not last nor be as abiding or unchangeable as are many unicellular forms of life.

This unchangeableness of certain forms of life through unimaginable antiquity is impressively illustrated by those unicellular algæ called Diatoms, whose survival may be largely due to the indestructible case of flint which each individual of them forms about itself. Here we find that inscrutable, sticky thing called protoplasm fashioning coverings for itself of the most varied and exquisite patterns in Nature made out of pure silex, some in spheres,

others in squares, others in triangles, others in spindles or veritable microscopic canoes, many of them with most beautiful colors, and all with delicate lines coursing over them. As the powers of great telescopes have been rated according to their resolving certain nebulæ into distinct stars, so the powers of microscopes have been judged according to their ability to resolve the lines on certain diatoms into linear dots, as in a copperplate engraving. But whole strata of rocks have been found in different parts of the world made up chiefly of the skeletons of diatoms. One such near Richmond, Virginia, is of much commercial importance for making polishing powders, and is even used in the manufacture of dynamite. But I have found in the sediment of a pool in our Central Park a number of the same species of diatoms which are taken out of rocks of the Cretaceous Period! And these liv-

ing things are still at their proper business the world over, for the bases of the high walls of ice which the sea washes around the great Antarctic continent are brown with them.

But for pure antiquity and unmitigated conservatism in keeping to old ways, those living things called Foraminifera take the palm. But for them geology would be only a physical science, such as a professor of it would find now on the dry, lifeless Moon. The foraminifera, instead of choosing flint to clothe themselves withal, have taken for that purpose the carbonate of lime which abounds in sea water, with the result that a great part of the crust of the globe has been constructed by them in the form of massive strata of limestone, chalk cliffs and deposits, great both in thickness and in extent. It is doubtful indeed if there be any limestone which does not owe its origin to these organisms, be-

cause marbles which show no traces of them prove on examination to have been subjected to far fiercer heat than that which would consume the remains of organisms in kiln-baked brick. This heat may have been engendered in many cases by the violent crumpling up of rocky strata during great movements of the earth crust, thus changing the original limestone deposits into veins of marble.

But elsewhere limestone proves on examination to be a very curious thing, full of minute holes which are really where little canals have been cut across, and which canals cannot possibly be of mechanical origin, for no mineral grains can be made to take such lines. Instead it is now demonstrated that it is all done by an animal organism which, when first identified, was imagined to fulfil all the conditions for a beginning of unorganized life, and therefore was called sarcode. A particle of this

jelly-like sarcode is observed in living foraminifera to throw out long threads which, however, are soon delicately encased by carbonate of lime, and as this shell remains after the animal which made it dies, so it stays as a slender tube of stone, thus explaining both the canals and the holes through which the sarcode threads exude, and from whence the name foraminefera. It has been demonstrated, however, by Oscar Hertwig and by other competent observers that this apparently simple sarcode contains that great official, the Nucleus, with all his high prerogatives, to whose agency must be attributed the remarkable constructive powers of these organisms. Some of their kinds live in fresh water where they, however, have no lime to work with, but their protoplasm is equal to the occasion, for they then make an envelope of Chitin, a substance which is the animal analogue of vegetable cellulose.

Foraminifera therefore are virtually unicellular, though with the important difference that they have no cell wall. Instead their protruded threads of protoplasm wherever they meet start a new organism of their kind and thus may make a collection of relatively great size.

We reproduce a plate here from Dr. W. B. Carpenter's article in the *Encyclopædia Britannica* on the Foraminifera, of the forms produced by them as they are found in limestones, which shows at a glance that they can no more be accidentally thrown together thus than a piece of printed newspaper can spontaneously come into existence anywhere. The bit of newspaper may tell something about the earthquake of Messina, but the limestone inscription by the foraminifera may as plainly tell a story of the doings of life and of nothing but life, some forty million years ago.

FORMS OF FORAMINIFERA

One needs, however, first to take some exercises in thought expansion before this story can be fully appreciated. Limestone strata, as we have said, make up a great part of the crust of the globe. But when we study how the strata succeeded one another in time, we become staggered with the signs of the presence of the Eocene Canadense in the limestone underlying the Laurentian rocks. Whole mountain ranges then towered above the sea and sank again; sea became land and land sea; climates changed from warm to cold and back again; environment changed and changed, and yet these foraminifera are still at their ancient doings the same as ever, so that if the present ocean bed were raised as in former times, new chalk cliffs would appear as of old. As Dr. Carpenter says, these foraminifera as long antedated the first fossils of multicellular form in the Lower Cambrian as these

last antedate us. Therefore untold millions of years of active unicellular life passed before the time came for a single multicellular organism to come into being.

Having reviewed some of the aspects of the unicellular forms of the living kingdom, it is now time to consider their relations to our subject of the origin and nature of physical life. We may ask:

I. What is the answer to the question, How did life begin on this globe, and in what form or forms? The answer is that it did not begin in an accidentally formed jelly, for such an event never happened in millions upon millions of years and hence cannot happen now, for not a single bacillus, nor protozoon, nor diatom, nor any foraminifera can now be made by anybody.

II. This primeval living matter when it came into existence did not forthwith begin to vary in all directions, because these

old unicellular things vary the least of anything on earth. Mountains may change, but not diatoms nor protozoa.

III. They were neither created nor modified by their environment, because all conceivable changes of environment have passed over them in their long story without ever having made them at all different from what they are now. Some of their species died out, perhaps of pure age, but not from destructive environment, because those forms which still exist are neither their survivors nor successors, but can be found to have been living and multiplying and acting through all the past ages.

How, therefore, is all this greatest story of physical life to be accounted for? The answer is one which will have to be repeated more than once as we proceed, namely, that we do not know, nor apparently does anybody else know. It is only uninstructed impatience which will assert

that more than a tithe of the laws of life have been as yet thoroughly discovered and known.

Because it was not from lack of susceptibility on the part of unicellular organisms to every alleged influence of environment that their unchangeableness was due, for their living forms now show as much sensitiveness to such influences as do other living forms, and hence presumably they always have done so. Among bacteria, for example, a severe struggle is always going on between different kinds for possession of the field. One of the greatest difficulties of the bacteriologist, when he tries to isolate any one form on his culture medium, is to prevent it from being invaded by other bacteria which soon exterminate his chosen kind. It is the word, contamination, which vexes this scientific experimenter's soul, more than that of any gardener when he sees weeds multi-

plying in his carefully tended beds. Likewise our great disinfectants, fresh air, sunlight, and washing, all act by destroying or weakening bacteria by causing changes in their environment unfavorable to their growth. Even the foraminifera find the Arctic seas too cold for them. But notwithstanding all this susceptibility to environment they hold on. The tubercle bacillus, though only seven minutes' exposure to sunlight kills him, yet has remained the same bacillus for thousands of years, nor once shown a fancy to become an anthrax bacillus nor a cholera vibrio, nor anything else but a tubercle bacillus. It must be some unknown power or principle of life which first gave origin to these living things and by which they remain the same to-day, yesterday, and for the future. This power or principle of life we can now only designate by the letter X, and many more such Xs we are yet to encounter.

Meantime, this great division of the living kingdom still exists as great as ever, and proportionately great in its influence upon the life of all present and more recent living things, ourselves included. In our next chapter we shall see that we live here only on temporary sufferance by the unicellular things, which sooner or later will put an end to our earthly existence. This subject, therefore, becomes a very practical one for us, multicellular beings, as all our Health Officials will testify.

On the other hand, we cannot but consider it strange that this greatest of the divisions of the living kingdom is wholly ignored by writers on biology. Darwin himself never once referred to it, though as his great work had for its title the *Origin of Species,* he would have found better examples of settled and definite species among the bacteria alone than he would have found anywhere else. This

omission of the first and longest chapter in the history of life on earth is parallel to Victor Hugo's views on the people, institutions, and laws of Great Britain based upon his observations of the inhabitants of the Channel Islands, Jersey, and Guernsey, because they spoke French!

Considering what the principles of history are, this usual beginning by biologists of the story of life on earth with the late appearance of the multicellular forms, is like a philosophical history of the great American Civil War opening with the year 1861, without a single reference to any of those antecedents which profoundly influenced both the inception and the course of that conflict.

But the mention of the tubercle bacillus alone suffices to illustrate the importance of the relation of this great kingdom of unicellular life to us. For ages upon ages this mighty micro-organism has waged

a cruel, destructive war upon the human race. After fifty years of observation and study of its ghastly doings, I can say that I would rather have the power to cause the tears shed on its account to cease than to be the greatest official or the greatest owner on the earth. Meantime its absolutely specific properties, which remain unchanged through the centuries, show that a physico-chemical explanation of the origin of this ancient foe can be expected only by uninstructed intellects.

CHAPTER IV

THE METAZOA, OR THE MULTICELLULAR FORMS OF LIFE

UNLIKE the Unicellular department of life, whose chief characteristic is fixity, that of the Metazoa is development. This development is not alone into a great variety of forms, but much more into a progressive elevation in function, or in the kind of work which is performed. Thus connective tissue cells, whose working is purely mechanical, are inferior to muscle cells, whose chief function is to pull and then to relax, for the relations of muscles to animal heat do not concern us now. But this muscle function of contraction and relaxation is simple compared with the functions of a collection of nerve cells. As function, however, is a gauge of life,

we may say that muscle cells are much less alive than the nerve cells in the spinal cord, and these in turn much less alive than nerve cells in the brain.

But what is meant by the term, alive? It is altogether too great a word to be defined. An insect is alive, and a stone is not. A little spider can make a web, which nothing however great if it is not alive can do. Only that which is alive can "make" anything. Hence in the metazoa one form is more alive than the other below it, and so on through the whole series from a simple living growth to living movement, and then on to sensation, thought, and purpose.

But this development of the metazoa was very slow in its course, the slowest, greatest, and last of all being nervous development. We might almost liken it to a prolonged course of education, each succeeding class learning what its predecessor had, and then adding to it.

It is this great feature of progressive development which has led biologists, from Darwin down, to restrict their attention to the metazoa. As we have already discussed the various theories propounded as explanatory of the course of development, we need not recapitulate them here. But a great and hitherto insuperable difficulty inexorably and equally attends all these speculators from the very start. If they had only full-grown plants and animals to deal with, the task would be comparatively easy. But, as we have seen, each metazoan form of life begins as a single microscopic cell, which is then more itself and nothing but itself than it will ever be afterward. In other words it looks at first altogether like one of those eternal unicellular things which never change nor develop for millions of years. But that which makes the vast difference between this metazoan unicellular thing and the

old unicellular things must all depend on the internal organization of its microscopic body. There is no way to get round that fact. The whole hereditary past and the whole developmental future, down to its smallest details, are together locked up in that minute speck of living matter.

The imagination itself refuses to picture at this stage what the internal organization of this wonderful little dot must be, and asks to wait till its subsequent behavior can be observed. Accordingly, the first thing noted about this metazoic cell is that instead of reproducing its like in all particulars as formerly, it divides into two cells, and these then into four, and these into eight, and these again into sixteen, and so on into an indefinite number of divisions.

But now comes the greatest of all the mysteries of physical life, to which is

due the difference between the old order of things and the new. Multiplication of cells, all with fixed hereditary and specific properties, was a great feature of the old order, but each cell was then an independent and finished living thing. In the metazoa, on the other hand, not independence but *interdependence* of cells is the absolute law. Their cells are never free unless they are being cast out of the community. A mere indefinite multiplication of their cells, in which they are said to proliferate indiscriminately, or even a sign of weakening of their reciprocal interdependence, signifies disease and death. All their cells instead are held together by a wonderful something which "organizes" their development along very definite lines. Thus in the higher animals after the dividing but adhering cells have come to resemble a mulberry in appearance, a division into three layers soon appears. From the first

layer develop in time, by various infoldings, the nervous and some skin tissues; from the second the connective tissue, the muscles, blood-vessels, and bones; and from the third the lining of the alimentary canal and its associated viscera, etc. If the further steps of development of organs out of these primary divisions had not been carefully followed, no one would dream what the word "differentiation" used by biologists to denote the process, means. It means that each cell, as growth goes on, takes its place where it ought to, in other words along predetermined lines. Every one of the many and diverse tissues, for example, which make up an eye, fit their places as parts of an eye and not of an ear. And so of the component parts of all the other organs. Fitness local, fitness general, fitness universal meets us at every turn, and so sure is this interdependence and interrelation of parts that an anato-

mist can often reconstruct an animal from a single tooth.

All these internal adjustments present at last an infinitely more complex and complete mechanism than the watch which Paley instanced as an illustration of intelligent design in the making. Paley's argument, however, in our times has been quite displaced by the great conception of mechanical development, or as it is called, Evolution, a conception which while true enough in principle is so far wholly unprovable in details. Evolution through descent of the later from earlier forms is believed in by all biologists, however diverse their opinions about what the process of evolution itself was. But here comes the great difficulty, namely, that general descent does not afford the least insight into individual descent. The real problem of life, therefore, is how the microscopic single cell, with which each individual

among the metazoa begins, should virtually contain not only all the structural peculiarities of the body of its parent without variation from its hereditary pattern, but should also have the power to determine where the untold millions of cells to grow from it are to find their proper places in the future adult body. What combination of physics and chemistry could produce this thing, when the inconceivably complex internal make-up of such a microcosm as that single primordial cell cannot be conceived of even by metaphysicians?

But something by way of explanation had to be attempted, and therefore various theories have been propounded. Now theories are as indispensable in scientific construction as scaffolding is in the erection of a great building. The mistake, then, would be to lay the solid facts we get on the scaffolding instead of on the pre-

vious settled layer of stones, a mistake which is not uncommon. Hence Darwin, when he found himself confronted by this special problem, ten years after he published his book on the *Origin of Species,* propounded a theory to which he gave the name of Pangenesis.

This pangenesis postulated a well-nigh infinite number of small gemmules, which are given off by every cell in the body and which make their way to the primal microscopic dot, so that this contains a representation of every part of the parent body. But as a man who had lost his right leg would have no right leg gemmules to send thereafter, so a child born to him after his accident would be minus that leg. This and similar considerations led Darwin finally, with characteristic candor, to pronounce this theory "unfortunate."

Since Darwin, or at least for thirty years

past, eminent biologists such as Roux, Weismann, Hertwig, De Vries, Driesch, Boveri, Wilson, and a host of others, have been observing, experimenting, and theorizing, without coming to the least agreement on these subjects; many of them virtually reverting to Darwin's pangenesis, with the result as expressed by Prof. Wilson* (p. 433), "The truth is that an explanation of development is at present beyond our reach."

We would fain emerge, therefore, from the shapeless fogs of the realm of theory into quite another territory whose chief outlines are plainly discernible and which are these. That the old unicellular forms, which still hold the greater portion of the field, seem, most ominously for us, to have resented the appearance of the multicellular forms on this globe and have been

* E. B. Wilson, *The Cell in Development and Inheritance,* Macmillan & Co.

waging a ceaseless deadly war against them ever since. We have already seen that so soon as a tree or large animal dies, its lifeless body is at once attacked by unicellular forms in a most effective fashion, as if they would get rid of every trace of such multicellular things. But their activities are not only post-mortem. Instead the unicellular forms remain ever on the watch to break through every barrier raised by the metazoa for self-defence. The chief barrier is the thin basement membrane, as it is called, on which grow the cells of the external skin and of the internal skin or mucous membrane. So long as these covering layers of cells are healthy, billions of the enemy may accumulate there without effecting anything. The instructed surgeon, however, well knows that he cannot make the smallest incision or sometimes even puncture of this protective envelope without peril to

his patient from the inrush of unicellular invaders, and the great triumphs of modern antiseptic surgery are due to the practical application of the great principle that multicellular must be guarded at every point from unicellular life. In medicine the same principles are equally important, because if any part of the protecting envelope is damaged by inflammation or injury, straightway an entrance for the deadly old enemies is established.

But a second and important line of defence is found in the inherent power of the healthy bodily cells to resist the invaders. This is well illustrated by an experiment in which after minute injuries have been inflicted by long, fine, but sterilized needles in the liver, spleen, kidneys, and limbs of rabbits, and then a virulent culture of pus-forming bacteria is injected into a vein of the rabbit's ear; these bacteria then circulate with the blood over the

whole body without affecting any of its cells except just where the cells have been injured by the needles; there they at once begin to form abscesses. The uninjured cells are then said to be endowed with a vital resistance to the invaders, which is wanting in those cells which have been devitalized by injury. A third line of defence is found in the healthy blood itself, which contains well-identified ingredients called opsonins, which enable the white corpuscles of the blood to attack the invading bacteria and eat them up.

But what is this all-important vital resistance? We need not say how important this is when, if a colony of tubercle bacilli finds a lodgment in a man's lung, his prospects will then depend on his local or general stock of vitality. The lower this is the sooner his funeral.

Meantime we have been reading the assertions of a school of biologists, that

there is no such thing as vitality or vital force. The trained physician feels then like bidding these mere theorists to hold their peace, for the principles of his great science of Hygiene are as well settled as those of any science whatever. Those principles, in short, are to help life fight life, that is, so to promote, on the one hand, the vitality of the individual by every means possible, that he can successfully resist invading micro-organisms, and, on the other hand, to make his victory easier by weakening the vitality of the unicellular enemies. Vitality, therefore, is doubly enlisted. The physician strives to increase the general health of the individual by good food, fresh air, sunlight, cleanliness or washing, and exercise. Meantime if he enters the dark, close rooms of a crowded tenement, he knows that pernicious micro-organisms are there in countless millions. But fresh air makes

most of them sick, light also enfeebles them or kills many of them outright, cleanliness, for the same reason, he elevates into a religious duty, and he is very particular in his inquiries about foods, especially milk, which he insists must be sterilized, or in other words have the bacteria in it destroyed. Chemistry and physics he never thinks of except as adjuncts in a purely vital war.

In practical medicine this subject of vitality never leaves us. Serious diseases are not always due to micro-organisms. Different physical causes may lead, for example, to progressive heart and kidney disease, in which the physician vainly tries to arrest the downward course. Finally things take a turn which has led medical authorities to make the seemingly paradoxical statement that but few people die of their diseases. It is because the slow, devitalizing effects of previous disease on

the body cells, especially in chronic heart and kidney affections, at last open the way for a host of micro-organisms to enter unopposed, and the post-mortem table then reveals how the actual cause of death came from a vast invasion of what are called the terminal infections. The survival of the fittest among metazoa therefore belongs to those who have the most vitality.

Solely to illustrate how the importance of these principles cannot be over-estimated in their practical applications, I will relate a recent personal experience. On January 26, 1909, I was called in consultation to see a little girl five years of age, who six days before began with a severe attack of scarlet fever. On the third day of this disease malignant diphtheria also supervened, and a thick membrane with a gangrenous odor covered all the visible surfaces of the throat, while the glands of the neck were greatly

swollen. I told the attending physician that the child would not probably die from her two infections, but from the general invasion through her ulcerated throat of numberless streptococci. As the child could not swallow, she was to be treated without any medicine, for the hypodermic injections of strychnine for stimulating the failing heart which the physician had been giving would be no more efficacious against the condition than if the little syringe was emptied into a fire. The only recourse left was to freely douche the throat as one would wash a dirty sidewalk with a hose. We might thus wash away the armies of micro-organisms and stop the further absorption of the diphtheria toxin from the decomposing membrane, while the patient's vital powers might be able to overcome the organisms which had already gained entrance, provided that no further additions were allowed. With

a rubber ball between her teeth to keep her mouth wide open, a couple of gallons of hot water with chlorate of potash and peppermint were poured into the mouth every two hours night and day, from an elevated fountain syringe: for if the mouth be kept open nothing is swallowed, but the current strikes against the back of the throat and returns by the tonsils, washing everything before it as it pours out of the mouth. I saw her again on the 28th, and was gratified to note a favorable change from the deathly expression of her face at the first visit. She still could not swallow, but the glands in the neck had begun to diminish in size, though much membrane remained in the throat. On the 30th I found that she could swallow, but that there remained the following complications to expect, like so many rocks in shooting rapids with a canoe. First the scarlatinal agent would invade

the ears; then twenty-five per cent. of deaths from scarlet fever are due to pneumonia; then pleurisy is especially to be dreaded in these cases, as it so often ends in the abscess of the pleura called empyema: then death might be caused by the diphtheria toxin dissolving, as it were, strands of the heart muscle, and lastly streptococcic invasion of the kidneys might end the scene. All of these dangers occurred to the child in their order except the last. Abscesses in both ears developed the next day, but a skilful aurist was at hand and freed the ears completely. This, of itself, was no small gain, for many cases of hard hearing throughout life date from the ear inflammations by scarlet fever in childhood, and I have been told that the same cause accounts for twenty per cent. of the deaf mutes in our asylums. On February 2, I found a patch of pneumonia with pleurisy

in the left lung between the shoulder-blades, but in five days the child's vital powers dealt successfully with them both. She was now quite hungry and always had her doll with her. Lastly, the weak intermittent pulse showed that the diphtheria poison was doing its work. Now on the twenty-fifth day of her illness for the first time she took medicine, but it took longer to relieve this complication than in the case of any of the others, before she finally recovered completely.

I have told this long story simply to show what a great and real thing vitality is. The physician's duty is to see to it that vitality has fair play in such a battle for life.

Therefore, instead of regarding the principles of Hygiene as one would general dictates to be good and virtuous, these truths furnish quite specific reasons for attending to health, for only thus can we

postpone the inevitable end. Because the supreme fact is that not by *physical* causes is our stay on earth usually ended. Physical causes may occasionally terminate life by storm, earthquakes or flood, or through human perversity by wars, but aside from such happenings it is by the agency of a great living kingdom that our mortal bodies return dust to dust.

It is also life which destroys life when death is caused by those dread and well-named malignant diseases, cancer and sarcoma. Never before in medical history has there been such diligent and intelligent search for the origin of these terrible affections as now, until it begins to look as if instead of coming from the old class of unicellular micro-organisms they come from a native metazoan cell which has deserted to the enemy. As with other renegades its greatest hostility is to its old associates, and it is all the more dangerous

because it retains some of the metazoan powers.

We can explain this in a few words. We have said that the great wonder of a metazoan body is the interdependence of its cells, each having and each keeping its own place. Moreover, though each metazoan cell retains its original endowment of indefinite multiplication, yet it always holds this in check in deference to the rights of its neighbors. If by any chance a normal metazoan cell be freed from neighbors, then it grows by the million till it comes to neighbors again, whereupon it resumes its proper consideration for their territorial rights. This is well illustrated when the surgeon implants on a large ulcerated surface on the skin which will not heal, minute pieces of normal skin grafts whose cells then multiply actively, far more than in their original place, with the significant addition that they now

throw out invisible germinal particles towards the nearest healthy cells at the edge of the sore, stimulating them to aid in forming a bridge across to the grafts. In time the open sore is thus covered with good skin, whose cells at once quit multiplying so soon as they join healthy skin cells.

But now among apparently the most well behaved metazoic cells there appears, no one yet knows why or how, a pure rebel against life's beneficent law of mutual dependence and co-operation. This rebel will grow and multiply just where it pleases without the least consideration for the traditional claims of others. Thus a cell from the mucous membrane of the lower intestine leaves that place and finds its way by the blood stream till it lodges in the brain, and then grows where it has no more business to be than a chimney sweep has to be ensconced in a lady's boudoir.

It not only pushes aside its neighbors, but invades their tissues and by intruding between nerves causes agonizing pains. Meantime it retains enough of its metazoan powers to give rise to organized growths or tumors with blood-vessels and other tissues, but with such poor vitality that these growths ultimately break down into repulsive and highly poisonous ulcers. Unlike the old unicellular enemies, it cares little for hygiene, for it counts emperors and queens among its victims as well as laborers and washerwomen, destroying those also who live moral lives just the same as those who do not. That its origin lies in the deepest processes of cell nutrition is shown, as we have already stated, by its occurrence in all vertebrates, not excepting fishes, for trout die of cancer as well as we ourselves.

These being the melancholy facts, about our only recourse is to detect the presence

of this enemy in the body as early as possible in his separate existence and then cut him out with the surgeon's knife before he can shed off any of his living germs. There is a faint hope that a sarcoma may find its match in a foe belonging to the unicellular camp, for in some cases an artificial erysipelas caused by inoculation with its bacteria has put an end to these growing tumors, and the mysterious rays given off by the element radium while undergoing atomic disintegration have, temporarily at least, put a stop to spreading superficial cancers. But when we consider how living these malignant things are, the prospect of successfully dealing with them is much less than with the old unicellular enemies.

CHAPTER V

THE GREAT FOOD QUESTION

For us to show how important the food question is to life may remind some of Artemus Ward, who, in an illustrated lecture on his travels, drew the particular attention of his audience to the fact, shown by his picture, that the highest part of a mountain is its top! That earthly life depends on food is equally clear and indisputable. But after all, things most commonplace may hide behind them some of the greatest and deepest mysteries of the world. Thus the ancient Greeks, after carving an Apollo Belvedere out of stone, placed the choicest viands and the finest wines before this statue of the god on his feast days. They well knew that this procedure was altogether a pious make-

believe. However life-like it may be, nothing but what is really living can be fed. Nor were the old Egyptians different when they surrounded their dead mummies with articles of food and drink for the spirits which hovered about them. Their mummies did live once, and why not let them eat and drink as they did before? The answer is the same: nothing without life can be fed.

Darwin indeed made the strife over the great Food Question about the only creator needed for calling living forms into existence, as Nature, he said, practically put the same question to all, namely, how to eat or keep from being eaten. It was the food question which set Natural Selection to shape the lion so that he would be well hid while waiting for his living meal on a gazelle, and in turn made the legs of the gazelle good for running away from him.

But Darwin builded better than he knew by making the food question such a great one in the process of life, for modern physiology has extended its scope from the bodies of animals to each cell in their bodies. In this undreamed of extension, Natural Selection is simply swamped, or rather it is like emptying a little brook into a sea. For now we find that the different cells of the metazoic body which had first given up their independence for interdependence, as we have described, on the food question reassert their original autonomy. Every cell of the body insists on having its own diet. They all must have food or they would die of starvation. They can grow and be themselves in shape and in function only according to what they feed upon. But a muscle cell cannot live on what a bone cell lives on, nor will the simple fare which suffices for a cartilage cell be ac-

cepted by a nerve cell which demands the most elaborate and varied menu of anything living. They all get what they want from that wonderfully composite, all-nourishing blood, but they carefully select just what they want and reject what they do not want. The cells which make hairs never allow any ingredients of the bile, which liver cells make, to enter them. And so on to the end. No such multiform discrimination meets us anywhere as in this realm of life.

This very particular selection by body cells of their food stuffs, is one of the great puzzles of biologists. Many of them have come to the conclusion that the cells know so well what they ought to have that they must be actually endowed with consciousness and choose accordingly. Professor G. Bunge * of the University of Basle quotes

* *Textbook of Physiological and Pathological Chemistry,* P. Blakiston & Son, Philadelphia, 1902.

in illustration the observations of Cienkowski on a minute ameba called Vampyrella, that will take but one form of food, which is a particular variety of algæ, the Spirogyra. The Vampyrella creeps along among numbers of other algæ until it meets with a Spirogyra, to which it then affixes itself and perforating its cellulose coat it sucks in the contents of its cell, and then travels in quest of the next Spirogyra, to repeat the process. Cienkowski never saw the Vampyrella attack any other class of algæ, or take up any other substance. Vaucheræ, Edogoniæ, etc., purposely placed before it, were always rejected. "The behavior of these single-celled creatures in their search after food, and in their method of absorbing it, is so remarkable," says Cienkowski, "that one can hardly avoid the conclusion that the acts are those of conscious beings."

We may say that similar discriminating performances are shown by certain vampires in our money markets, who show no interest in anybody except in those who own stocks and bonds. To these they attach themselves and soon transfer all their stocks to their own pockets ere they pass to the next victim. "But," Professor Bunge continues, "just as the Vampyrella picks out the Spirogyra from amongst all other algæ, so do the epithelial cells of our intestines select the fat drops and reject the pigment granules. We know that these intestinal epithelial cells prevent the absorption of a whole series of poisons, in spite of the fact that the latter are easily soluble in the gastric and intestinal juices. . . . Also in all secreting cells we find the same mysterious power of selection."

Similar doctrines attributing reasoning power to the cells, and thereby to the lower

animals and plants, all based on the food question, are advanced by such biologists as Delfino, Cope, Pauly, and Firanci, while Sir Francis Darwin, son of Charles Darwin, in his inaugural address as President of the British Association of Science, at Dublin, 1908, says: "It is impossible to know whether or not plants are conscious; but it is consistent with the doctrine of continuity that in all living things there is something psychic, and if we accept this point of view, we must believe that in plants there exists a faint copy of what we know as consciousness in ourselves."

But at this point we must part company with these learned observers. Though admitting that life is fundamentally one in both plant and animal, yet in common with most of our fellows we regard consciousness as the sole attribute of certain sentient nervous centres, and hence cannot

but regard those whose steps logically lead them to conscious potatoes and cabbage heads as well on the way to absurdity.

Quite another aspect of this problem in cell life, and one which apparently affords considerable support to the anti-vitalists, is presented by some researches in medical science, on the subject of Immunity. To determine why a single attack of some infectious diseases renders that person immune against a second attack of the same, or why some persons seem to have a natural immunity against infections in general, while others are very susceptible to them, or why some infections confer only temporary immunity or none at all against their recurrence, are certainly questions of much practical importance. Their investigation has led recently to some of the most abstruse speculations in the history of medicine. Now theories are valuable

in proportion to their number of explanations, and as no demonstrated facts long remain isolated in science, so one largely accepted theory of the mechanism of immunity, called Professor Ehrlich's side chain theory, is found ultimately to have important relations to our subject of cell assimilation of food, or in other words, how it is that food feeds us. It is difficult, however, to lead the general reader along the intricate lines of this hypothesis without giving him a headache, and so we will only attempt a necessarily imperfect outline of it, by beginning with a rough illustration. If the reader has ever had the pleasure, or to some the horror, of seeing that fresh-water polyp called a hydra fusca in a water receptacle which allows him to be seen with a low magnifying power, he then looks like a great octopus swinging his ugly arms, all covered with contractile nodules, about in the water. A

careful inspection shows that he holds several long, fine fish-lines at the end of each of his arms, these lines terminating in a little round poison sack surmounted by a perfect barb, thus, Swimming actively about are many little white crustaceans called daphnes, wholly unmindful of the hydra, when suddenly one of them is seen to swim no longer. Watching this now motionless daphne, it is found that one of the fatal barbs has struck him and that he is motionless because paralyzed by the poison from that little sack. Then the hydra pulls the crustacean in as a fisherman would a trout he had hooked, and soon the hydra eats him up. Now those living cells in our blood called the white corpuscles are capable of throwing out what are termed their pseudopodia: these have been seen to seize invading bacteria and to draw them in to be devoured and digested by the white cell. This phenom-

enon forms the basis of Metchnikoff's phagocytic or cell-eating theory of immunity. But some bacteria kill, not by themselves entering the blood but by their first securing a lodgment in some part where they stay, generating a virulent soluble poison which poison, and not the bacilli, is then absorbed into the blood. This is the case with the tetanus or lockjaw bacillus, and hence a tetanus antitoxin must save a patient with lockjaw in a different way than by Metchnikoff's phagocytes. With Ehrlich's side chain theory, therefore, our hydra illustration would have to be modified into imagining the chains of nodules on the hydra's arms as themselves shooting out lines of attraction which arrest the poisons as they pass in the blood and draw them in to be incorporated into the nodule.

But these lines of attraction must be purely chemical in their nature, or in other

words lines of chemical affinity for ingredients in the poisons, and the phenomenon itself, therefore, has received the name of chemio-taxis, or chemical drawing. Therefore on this principle every cell of the body when it draws its food from the lymph which comes to it from the blood, selects what it wants by chemio-taxis, that is, by a power or property which is not essentially different in nature from other chemical affinities. Therefore, our supposedly living attribute of nutrition by feeding turns out after all to be a thing of chemistry.

Admitting all this to be true, yet chemio-taxis no more explains life itself than anything else does. It is life which produces chemio-taxis, and not chemio-taxis which produces life. Our former comparison still holds that it is not smoke which causes fire, but it is fire which causes smoke. Life produces all kinds of chem-

ical things, with this important difference, that organic chemistry, i.e., that which is produced by living agencies, is vastly more complex in its processes than inorganic chemistry. A molecule of water, for example, has only three atoms in its composition, two of hydrogen, and one of oxygen, but a molecule of cane-sugar has forty-five atoms, and, moreover, these atoms are so differently arranged in different sugars that a painstaking authority has written five volumes on the sugars alone, and is not through with them yet.

Whatever else, therefore, may be said of organic chemistry, this is certain, that something enters into its processes which is not found in any other chemistry, that something making its products far removed from all other chemical components in the make-up of their molecules.

But if each kind of cell in the body has its own chemistry, we may well be staggered at the infinite number of shapes and forms which vital chemistry assumes. Thus we must have a different and special chemio-taxis for the cell which is helping to make a toe nail from one which is building up a centre for sight in the brain cortex, and then untold thousands more of varying kinds of chemio-taxis the body over.

It is the frequent recurrence of such embarrassing conclusions which is making many of the younger biologists weary with all physico-chemical explanations of life. As J. E. Haldane, M.D., F.R.S., Professor of Physiology in the University of Oxford, remarks: "As a matter of fact, the physico-chemical theory of life has not worked in the past and can never work. Those who aim at physico-chemical explanations of life are simply running their

heads at a stone wall, and can only expect sore heads as a consequence." *

* Address as President of the Section of Physiology, Brit. Assoc. Science, 1908.

CHAPTER VI

ADAPTATIONS

Professor E. B. Wilson * says, "Whatever position we take, the same difficulty is encountered, namely, the origin of that coordinated *fitness,* that power of active adjustment between internal and external relations, which, as so many eminent biological thinkers have insisted, overshadows every manifestation of life."

They might well say so.

The word fitness at once suggests mechanism. The different parts of a watch would not make a watch unless they were made to fit into each other. The same holds true if it be a living mechanism. Moreover, it is not the materials out of which this mechanism is composed which

* *The Cell in Development and Inheritance,* p. 329.

make it a mechanism. Very far from it. We might reduce a watch to powder without the least loss of its materials, but then we would not have the watch any more. So a living mechanism is not the same with its component materials, but justifies our speaking of it as a *living* mechanism only when its parts are adjusted to each other with a fitness which is beyond that of any non-living mechanism in the world. We shall see that there is no fitness like a living fitness.

A great steam engine, for example, is not near as complex, nor does it require a tithe of the adjustments of its parts with one another, which are necessary in a human eyelid. Not counting the lachrymal gland and its appendages, an eyelid of ours is anatomically made up of at least forty-eight different structures and special arrangements of tissues, any one of which, if it did not fit in with the rest,

would give trouble. Thus the two eyelids are kept in shape in a totally different way from the two lips of the mouth, by a peculiar ring which for long was mistakenly supposed to be cartilaginous, whereas it does not have a cartilage cell in it, but instead is made of two plates of denser fibrous tissue than is found anywhere else in the body. Then it would be unfortunate if the plate in the lower eyelid were of the same size and shape as that of the upper eyelid. For one thing it would disfigure a lady more than the worst squint. Nor would it do if there were as many eyelashes near the inner angle of the eye as at the other end; nor if the eyelashes of the upper lid were not more numerous and longer than those of the lower lid, and more than all, if those of the upper lid did not curve up and those of the lower lid curve down. To make these hairs grow that way and not like

the hairs of the eyebrows or those of any other part, a special arrangement of the cells at their roots had to be provided. Then to keep the eyelids from sticking together in sleep, appear rows of twenty to thirty very peculiar glands composed of straight tubes with buds, on their sides, and secreting in their special cells an oily substance different in chemical composition from any other secretion, etc., etc.

Such are the visible structures of an eyelid, but, as every medical student knows to his sorrow, the microscope has more than quadrupled the number of facts which he must learn about the structures of organs, all of which have to do with fitness. In the case of the eyelid he may well add facts about the beginning of eyelids in both human and in comparative embryology.

But to stop in the consideration of adap-

tations at an eyelid, and not pass on to the Eye itself, would be like a tourist failing to go beyond the railroad station of the great city which he had reached. There is scarcely a tissue of the body which is not represented in the eye, besides a number of others not found elsewhere, and if we include the connections of the eye with the brain, the number and variety of its specific adaptations well-nigh exceed computation. Darwin is reported to have said that the eye made him shudder when he thought of accounting for it by Natural Selection. Now the radical difficulty with natural selection is that it cannot produce anything, nor originate anything, least of all produce an adaptation, whether simple or complex. All it can do is to select and perpetuate an adaptation already made. When a housewife picks out of a barrel the apples which are beginning to rot, her selection has not produced a

single one of the sound apples which remain. But this difficulty about the eye is not lessened by the fact that some of the earliest and generally simpler animal forms nevertheless had extraordinarily complex eyes. Some creatures living in the darkness of the ocean depths provide themselves with what are virtually lanterns to help their eyes out. This means that life has no limits in her ways for helping functions. But where no seeing is possible, life gives up the useless attempt and bids the fishes in the underground rivers of the Mammoth Cave to go without eyes. This may be called a negative adaptation, the opposite of that of the eagle's eyes as he soars towards the sun.

However, we need not dwell longer upon this instance of a living mechanism which in a small space shows more examples of fitness in adaptation than the

whole world of human mechanical devices, and proceed to what seem to be much simpler arrangements for doing special work. Thus as to the intake of oxygen and the outgo of carbonic acid in breathing. Professor Haldane, whose researches on this subject are highly rated, remarks: "Liebig believed that the rate of respiratory change was regulated by the supply to the body of oxygen and of food material. If one breathed faster, the respiratory exchange was assumed to be also increased, just as ordinary combustion outside the body would be increased by an increased supply of oxygen. If, again, one took more food, it was supposed that the excess went to increase the rate of combustion in the blood, just as a fire is increased when more fuel is supplied. We now know that these assumptions were wholly mistaken, and that the respiratory movements, respiratory exchange, and cor-

responding consumption of food material in the body are regulated with astounding exactitude in accordance with bodily requirements. If, for instance, the body consumes more proteid, it economizes a quantity of fat and of carbohydrate equivalent in energy value to the proteid, so that from day to day the amount of energy liberated in the body is very steady." In other words, the body adjusts its chemistry just as it adjusts everything else.

The heat of the body is also kept up by chemical processes, but for that purpose more internal arrangements and adjustments to external conditions have to be in incessant operation than in the case of respiration. Even to enumerate them would require many pages, and more pages still to explain them. Thus the human body maintains just the same temperature, whether it be on the shores of

the Arctic Ocean or in the hottest regions of the world. The Esquimaux live where, during the long winter, the air is from 128 to 148 degrees colder than their blood, while the people of Zanzibar live for months where the air they breathe is 20 degrees warmer than their blood. More than a hundred years ago Dr. Blagden, president of the Royal Society, and Dr. Fordyce, F.R.S., stayed for twenty minutes in heated ovens which cooked a beefsteak in 13 minutes, without the normal heat of their blood meanwhile varying in the least. They reported that their watch chains were then too hot to touch, while the air which they exhaled from their lungs felt refreshingly cool.

Nothing, indeed, but internal derangements can change the normal temperature of the blood, and hence the value of the clinical thermometer in disease. But to explain fever itself pathologists have la-

bored and experimented for years on account of the complexity of the problems they encounter. One result is curious, and that is that fever is a good thing to have under the circumstances. Professor W. G. MacCallum * of Johns Hopkins University says: "It seems probable that every detail of this fever reaction is that which is best calculated to take its own special part in the making up of a whole well-ordered plan. The conclusion seems inevitable that this plan is one devised for the good of the organism and that fever in its essentials is a protective reaction."

It will be noted that biological investigators can hardly escape from using language about living processes which imply design and purpose. The celebrated physiologist, Sir Michael Foster, when

* New York Harvey Society Lectures, 1908; MacCallum on "Fever Processes."

asked once why a certain physiological fact was so, replied, "Because it wants to be so!"

If we did not prolong the consideration of the adaptations of part to part in the Eye, because the reader's patience would be exhausted long before they were all enumerated, what are we to do with the Nervous System? An old anatomist well said, the nervous system is the animal. He is all there, to be sure, with more special adjustments in his nervous make-up than in all the rest of his body. In fact its illustrations of marvellous fitnesses are altogether too many for us, and so we will leave the nervous system and allude, in conclusion, to the place which one of four mysterious organs has in the ordering of our physical life. These four organs, the Pituitary, the Thyroid, the Islands of Langerhans, and the Adrenal Glands, pass directly into the blood and not

through ducts, peculiar substances which are very necessary to life. The pituitary gland is a small affair from five to ten grains in weight, only its anterior half being of much account, and its resting place is in the sella turcica or Turkish saddle-like depression in the most solid bone in the body, at the base of the skull. Disease of this gland has been supposed to be the cause of those fearful deformities in the growth of the skull and of other bony structures to which the name acromegaly has been given. That it has important relations to bodily nutrition cannot be doubted, because its experimental excision leads in time to death with very characteristic symptoms. But as its physiological mysteries have not yet been fully solved, we must await their future demonstration. The thyroid also we omit, because more than two thousand books and articles have been published so far on

Graves' Disease, which most writers, but not myself,* regard as a disease of this gland. For occasioning unending discussion, the thyroid in medicine is like the tariff in politics, and so we pass on to take up the Islands of Langerhans.

The Islands of Langerhans are peculiar gland structures imbedded in the pancreas and which add to the blood an internal secretion of their own wholly distinct from the secretion of the pancreas itself, which flows off to the intestine through its duct. Disease of these islands causes bread, the staff of life, to become highly poisonous, because such disease causes that mortal derangement, diabetes. But a most pe-

* The reader may consult my monograph on *Graves' Disease, with and without Exophthalmic Goitre* (Wm. Wood & Co., New York, 1904), which was written to show that the Thyroid is not primarily but only secondarily affected in this disease, a fact which has important bearings on its treatment. Also my article on Graves' Disease and its treatment, in the March, 1908, number of the *American Journal of Medical Sciences.*

culiar fact is that if a collection of cells from these islands, not larger than a pea, be engrafted in another part of the body where they will grow, no diabetes will follow, though the pancreas itself be removed. We can guess from this why diabetes is the most insoluble problem in medicine.

We now pass on to take up the adrenals, those small organs whose experimental removal kills much more quickly than the removal of the kidneys themselves.

For the nervous system to make glands seems rather a come down, to be justified only by the high and important rank of the structures so originated. But we may expect anything out of the way in the performances of the Great Sympathetic, that third great nervous system in us which we know to be more closely related to our vitality than the spinal cord and the brain put together. But so mysterious are the

doings of the Great Sympathetic that physicians do not often mention it because they know so little for certain about it, except that it holds very important relations to the chemistry of the living body, while to its nerves is committed the great office of regulating the supply of the blood to every part as it is needed. Thus the stomach needs about nine times more blood when it is digesting than when it is empty. As food enters it, its vasomotor nerves as they are called, which ramify on the coats of the arteries and which are derived from the sympathetic, relax the stomach arteries to flush all its secreting glands, and then when it is empty they shut the supply off. Without this incessant nervous regulation of the blood-vessels we should soon cease to live, because were the great arteries in the abdomen to relax they could hold all the blood of the body. This sometimes occurs with a quickly fatal re-

sult. Hence we are always uncomfortable if these sympathetic nerves are irregular in their duty. Thus a sunstroke so injures the sympathetic in the neck that for years the patient's head and face flush on the slightest provocation. Now these vasomotor nerves lose all power to regulate the arteries if the adrenal glands are out of commission. And the reason seems to be this: That early in embryonic life a twig of the renal (kidney) plexus of the sympathetic becomes rolled on itself like a ball of twine. In time it breaks off from its parent stem, and, becoming enclosed in a capsule, adheres to the top of the kidney as a fully formed adrenal gland. The marvellous thing then is that these adrenals add an internal secretion to the blood, which contains a definite chemical substance which combines with acids and forms salts, and is called adrenalin. This adrenalin is virtually a drug, and as it

has been isolated, it is sold over the counter like any other drug or medicine, because it has many properties of much value to the physician. It is also very powerful, for only one eight-hundredth of a grain of it will uncomfortably raise the pressure of the blood in all the arteries of the body. Now for our present purpose, the fact is interesting to state that if the adrenals are cut out, one cause for the rapid supervention of death is from paralysis of all the vasomotor nerves. Those nerves cannot act if there be no adrenalin in the blood.

Moreover, chronic disease of the adrenals causes a fatal affection called Addison's Disease, the patients finally dying from pure weakness. A strange bronzing of the skin in large patches also generally accompanies this complaint, which points to its connection with derangement of the sympathetic. Three patients with Addi-

son's disease I have kept for a number of years from succumbing to it, by daily doses of extracts of the adrenals of sheep. Here, therefore, is another adaptation, which would make all the other numberless adaptations useless if it alone were wanting.

In the foregoing brief review we have merely given examples, out of any number of others, of adaptations in the living body, by far the most of which, if they failed to fit perfectly, would involve death. No satisfactory account of the origin of any of them has yet been given. On this one subject of adaptation the words of Professor Kellogg may well apply, "We are ignorant, terribly, immensely ignorant." * But he sensibly adds, "Our work is to learn, to observe, to experiment, to tabulate, to induce, to deduce." They must all occur according to natural laws,

* *Darwinism To-day*, p. 337.

and to investigate the operations of natural laws is the great and honorable province of Science, because she deals with facts or with reasoning based only on facts. But in such an infinitely complex problem, more so than any in physics, chemistry, astronomy, or in any other science, it is no discredit to the learners that they still have so much more to learn. One might as well reprimand a young class not through with their primers, because they could not read and forthwith interpret one of Browning's poetical conundrums in his *Rienzi.*

But a mental necessity impels one to ask, what is back of all these blind natural laws, to make their operations overshadow everything else for pure adaptive fitness? Laws never explain what makes them laws any more than the movements of the hands of a clock explain what makes those hands move so regularly. We know a great

deal about the laws of gravitation, but we know nothing about gravitation itself. So the laws of cohesion render steel good material for making knives, but cohesion itself could not make one knife. The only answer is that back of all law or laws is the supreme reality, Mind, and it gives a grander conception of that Reality when this is recognized as the cause of the uniform operation of blind natural laws without once changing their naturalness. The scientist may therefore go on in his plodding investigation quite sure that he will never be troubled with an unnatural law.

CHAPTER VII

AS TO OURSELVES

So far in our discussion of the problems of Life, we have not often gone beyond the province of a botanist or of a naturalist. All that we have said might have its illustrations in the life of a cactus, of a parrot, or of an antelope, because it is only life which we have been investigating, and anything living illustrates life. But all along the way there looms up as its termination and end that which dwarfs everything else, and which was termed by Huxley the Andes of Life—Man.* Until the road reaches the base of this great mountain range, our interest in it is not very exciting. We have been gathering just so much scientific information and

* Huxley, *The Place of Man in Nature*, pp. 119, 132.

no more. But so soon as we find that the trend is towards a scientific demonstration of the origin of Man himself, our mental attitude immediately changes. It is now we ourselves who are personally involved in the discussion, and none the less so because we are not to consider man from a metaphysical or philosophical or theological standpoint, but only as science must regard him.

But even then we feel that nothing which we have already passed quite prepares us for this task, because not only lofty heights, but also profound depths lie before us, if Man is to be accounted for. He is the problem of problems, every proposed explanation of which proves to be very incomplete. It is all very well to follow life unicellular to life multicellular, and then from forms now living to those long extinct, whose remains in the earth's rocky cemeteries show how all came

by continuous descent from primitive metazoa—but then what are We who are making this review?

Unhappily we are not like scientific beings from another world, visiting this planet to study its vital phenomena, but we are ourselves part and parcel of that which we are investigating. To say the least, this fact is curious, and naturally suggests the question whether after all we are really of this earth or only by some chance on it. Certainly this earth has no other self-examining species.

But before attempting any great ascent, much preliminary work is necessary, and so here, following as we should along the lines of the physical conditions entering into the life of man, we begin with his bodily senses. It is by them that he comes into relation with his physical world, because they afford the only means by which at first he can do so. He is an inner

centric self with the whole world outside of him, and so that world would remain but for these special sense organs, which, it should be particularly noted, are on one side so wholly physical that we can examine them with scalpel and microscope, but they connect at the other end with what is anything but physical, being instead wholly psychical. It is not the physical eye, but only the man himself which sees, though without the eye he could not see at all. Here, then, just where each bodily sense reaches his consciousness, is the man himself. This is where he is at home, and if we can only make his acquaintance in those private quarters, we will learn more about him than we can anywhere else. Both metaphysics and philosophy have filled the world with outside talk about Man, but for trustworthy information give us the testimony of his five bodily senses.

Thus, beginning with the sense of Taste, the lowest of human senses, since its chief function is to serve bodily nutrition, we find illustrated even here that generic dissatisfaction in man with narrow limitations. This impatience with limitations is our first private information about man, and we are never going to hear the last of it. For though the ass knoweth his master's crib and is satisfied with its healthy but monotonous diet, at a man's banquet, where his range of taste is illustrated, the air above, the earth beneath, and the waters under the earth are all called upon to furnish things for that table. The commerce of the world draws largely upon the products of every clime and region of the globe to supply what men like to taste. He would be well versed in geography who could tell where every article came from on the table of one of our ordinary mechanics. But the

creature at the crib has quite a sufficient reason for being content with his unvarying food, namely, because he is an ass!

But the same discontent with what he has got Man shows with all his other senses. None of them come up to what he requires of them. The other animals, all of whom have the same sense organs that he has, find these perfectly satisfactory for all their wants, but man finds his to be such poor instruments for him that he has to supplement the most important of them with devices of his own making. For he demands of his bodily senses what no other creature would think of asking: things to be seen which no eye was ever made to see, nor ear to hear, nor touch to feel. Finally, in his insatiable quest for information he parts company with his sense organs altogether, with the result, as we shall see, of incalculable additions to his knowledge.

All this is particularly well illustrated in the case of the Eye, for we may here appropriately quote the remarks of its most distinguished scientific investigator, Hermann von Helmholtz,* who says, p. 201: "Of all our members, the eye has always been held the choicest gift of Nature—the most marvellous product of her plastic force. Poets and orators have celebrated its praises; philosophers have extolled it as a crowning instance of perfection in an organism, and opticians have tried to imitate it as an unsurpassed model."

But after enumerating the many features of its mechanisms with their explanations, he proceeds, p. 219: "Now it is not too much to say that if an optician wanted to sell me an instrument which had all these defects, I should think myself

* H. von Helmholtz, *Popular Lectures on Scientific Subjects*, Appleton & Co., New York, 1873.

quite justified in blaming his carelessness in the strongest terms and giving him back his instrument. Of course I shall not do this with my eyes, and shall be only too glad to keep them as long as I can—defects and all. Still, the fact that however bad they may be, I can get no others, does not at all diminish their defects."

Helmholtz is here speaking of the eye only as an optical instrument used for the ordinary purposes of life, and for these he finds it abounding in deficiencies. He does not allude at all to its utter inadequacy as a help for us to go beyond our customary world. But ordinarily no one's eye recognizes anything clearly within eight, and with many, ten, inches of his eyeball. What is there to see within that distance? Not until a microscope was made could any one tell. It is a mistake, however, to suppose that this artificial supplement to

the eye ever magnifies anything. When we cross a street in order to read a sign we have not magnified its letters by doing so. We have simply brought our eyes nearer to them. And that is all that a microscope does. A three-inch glass brings our eyes to that distance of the object we are looking at. An inch and a half glass brings us so much nearer, and if then with a direct illumination we look at the centre of a common verbena flower, strings upon strings of more gorgeously colored pearls than any jeweller can show, appear to our admiring gaze. All this shows that the eyes which we brought with us at birth do not see a tithe of the beauties of Nature. With a microscope not much better than this, Leeuwenhoek, in 1675, frightened the world by saying that more animals live in our mouths than there were people in Holland! But with object glasses of higher powers we are said to see things magnified

200, 500, 1,000, or 2,000 diameters, which only means that different objectives, as they are called, bring our eyes within 1-4, or 1-8, or 1-12, or 1-15, or 1-25 of an inch of the object.

And what have these mechanical devices of ours for helping our eyes to see, not done for the human world? So important to all life is that living world about which our native eyes would never have given us the least information, that it is evident that no physical instrument can suffice for man, because he is so much greater than anything physical. All eyes made of protoplasm, including the eyes of the anthropoid apes, belong only to low origins and levels, but this mineral made microscope belongs to the Andean heights of Mind.

However, we have still other reasons for dissatisfaction with our eyes. They see Canopus, the second brightest star in

the heavens, as no larger than a bright jewel in a lady's necklace, though we know that since that star has no proper motion, as astronomers say, it must be immeasurably distant, and for it then to shine so splendidly, it is very probably more than a hundred thousand times larger and a hundred thousand times brighter than our own sun. But our poor eye can now answer: You know that I do not *report the exact truth to you about anything.* You should not trust me so, because, owing to radical defects in my make-up, I tell you that a man six feet high is only six inches high when he is a mile off. And as to the stars, you have had to make a telescope to help me out, but even with its aid the fixed stars remain beyond me, for I then see them as merely shining points. It is not by me, but by that greater power than mine in you, your Reason, that you learn not only how large Canopus is, but also by

another of your contrivances, that Canopus abounds in earthly materials.

We must leave for the present, other important lessons from the serious imperfections of this sense organ, to take up the Ear, only mentioning what is the most important fact of all, viz., that it is not the *faculty* of sight itself which is imperfect in us, but solely the instrument of that faculty which is so. If the faculty itself were deficient, we could not ourselves help it with anything, whether telescope or microscope, any more than we could help a man who had never learned to read, by giving him a pair of spectacles. The faculty belongs to us and not to our eyes, nor to our brains either, as we shall find further on.

The Ear is worse off than the eye in the narrowness of the range of the medium through which it catches sounds. While the eye responds to the vibrations of light

which travel 188,000 miles a second, the vibrations of sound travel only 1,100 feet a second. Sounds, therefore, soon die away in the distance, nor can a thousand voices singing together go much farther than one voice does, the same as, if instead of singing the crowd were throwing stones, but a few of the stones would go beyond the average distance of the rest. Nevertheless, the ear possesses certain intrinsic advantages over the eye. Instead of the constantly mistaken information which the eye gives, the ear is always accurate and truthful. Hence it was a great advance in medicine to enlist its aid in auscultation. It fails in our species only in its report of the direction of sounds, because for that purpose we have no movable external ears such as those of the rabbits and the equines. Unlike the eye, which chiefly informs the mind, the ear stirs the emotions. We can see a fish

writhing in its death agony without pity, but no one can so listen to an animal's shrieks of pain. This is as it should be, for however wrong the head, the heart should keep right. The ear also is intensely personal. It makes no mistakes about the identity of the voice it hears. Once, on the deck of a Glasgow steamer, I parted from a student friend, and we did not meet again for thirty-three years. I could never have known him then by sight, for time sadly spoils eye memories, but his voice told me who he was the moment he spoke. All such facts reveal why through the ear the profoundest depths of being are reached, because for some persons Music, instead of being only sounds proceeding from tongue, lips, or instruments, is to them the speech itself of the innermost soul. Beethoven composed some of his finest symphonies after he had become stone-deaf.

Nor has that great being who is back of each sense organ failed to remedy the deficiencies of the ear even more wondrously than those of the eye. I was once told that a gentleman wished to speak to me, and on my asking what he wanted his voice trembled as he said that his child had pneumonia. As his physician was with him we three then alternately spoke, and though they were hundreds of miles away, I could distinguish their different voices as readily as if we were actually together. It was by means of an electrified wire that the ear heard personal voice and tone transmitted a thousand times farther and faster than waves of air could vibrate. But what is that marvel compared with wireless telephony? Here is man bidding that mysterious ether which pervades the whole universe to become a human voice speaking to a human ear!

But far and away the Queen of our senses, and higher in rank than eye or ear, is our sense of Touch, because it is the only one of our senses which endows us with entirely new capacities. Yet it is so only in the human being, because in him alone can it do what it does in raising Man to the rank of a true Creator, or one who gives origin to things which would not exist but for his intelligent purpose and design. With these new capacities we can do what we please with anything physical on this physical earth. Thus a large audience may be spellbound by a famous violinist who seems to make his instrument sweetly talk. It all then looks so easy. He has no more fingers than I have, but if I should take that instrument in hand it would utter nothing but lamentable squeaks. So another musician commands a high price for each night's performance on the piano, because he has acquired such

a marvellous touch of its keys. But Civilization is out with her greatest shows on this occasion. The women there are simply indescribable for what they display in dress and ornament, and yet not an item of either would be procurable but for skilled handicraft. So the great hall itself and everything in it, whether for use or for embellishment, has been made by skilled handicraft.

But what is skilled handicraft? It is that which produces work according to a special training in each case of the sense of touch. It is not the eye which can make a microscope, nor the ear a trumpet. Practically it is the insensate hand made intelligent and guided by a human personality which suffices for everything. With a human personality, the sense of touch can take the place of the seeing of the eye and of the hearing of the ear, when these can no longer do either. Helen Keller

lost in infancy every seeing and hearing brain cell, but by the sense of touch she has become a highly educated woman, versed in the literatures of ancient and of modern languages, and an accomplished authoress as well.

Yet the sense of touch itself does not count, since a number of animals have a more sensitive touch than we have, but this delicate feeling in them falls so far short of reaching a human consciousness, that were all animals to unite in the attempt, they would still fail to make one ordinary pin. Without the human mind there can be no handicraft.

It is this bodily sense activating the hand which most reveals what man is and what he can do, for as the ancients said, feeling reaches the heart of being. In comparison, matter now sinks to insignificance. Like all other senses, touch ascends to the brain by its afferent nerves

and reaches there that Great Reality which by its efferent nerves tells the human hand to turn and deal with the properties and the forces of matter as it wills. Thus one can now take passage from the New York Central Depot, and in twenty minutes pass through seven miles of the subway which runs under the streets of two cities and under a river on which great steamers ply. Matter enough had to be handled ere the way was finished, but the designer decreed beforehand how every shovelful was to be removed. Also the marvellous bridge which spans the river overhead existed down to its last wire and bolt, in the mind of the great engineer who planned it before any part of it existed on earth. But we need not go on, for the whole earth is filled with the glory of man by his handiwork.

To some all this sounds trite enough, because everybody knows that man has a

wonderful mind. But just because every one knows this, the important scientific aspect of the subject is overlooked altogether. For as Science rates other animals according both to their bodily structure and their degree of intelligence, so she should scientifically account for the whole of man, for his mind no less than for his body. Science might as well limit her observations to his skin as to neglect explaining how, on her principles, his mind naturally fits into her scheme of the development of life on earth. The fact that he has an exceptional mind does not absolve her from a scientific explanation of that fact. In the rest of her ascending series of animal forms, Science has no trouble with any member of them, not excepting the chimpanzee. In him she finds that his mind or intelligence corresponds to his brain, and *vice versa*. But with the next primate, man, an immeasurable gap oc-

curs, not between the body or the brain of either, for in both these respects the two are similar, but there is a gap in intelligence for which there is no measure. It requires some thinking adequately to estimate how great that gap is, and we have been trying by following the lines of the physical connections of man's bodily senses with his mind to perceive how tremendous the break really is.

Years ago I was once officially engaged in counting the assets of a great bank, in the course of which I held in my hand a piece of printed paper, with which had I owned it myself I could buy the cattle on a thousand hills. But had it been offered to any chimpanzee who has ever been evolved, to choose between that piece of paper and a cocoanut, the cocoanut would have been reached for every time. The nut and the paper belonged to two worlds of things infinitely apart.

The fundamental distinction between the two lies in the transcendent fact that Man is a person, something which no other animal is. A person living in a world of persons shows in his most ordinary commonplace acts that there can be no real identity between himself and animals. Writing a letter and then dropping it into a street mail box implies these differences from the denizens of a cocoanut grove: a city with everything which makes a city; a great country where government provides post offices by which letters may go anywhere if properly stamped; the faculty of speech expressed now not by mouth but by a typewriting machine on its special letter paper. How can biology explain *any* of these things? The most brilliant discoveries made by biologists have not been made in man, but in worms, as by Wilson in annelids, and by Boveri in ascarides. These biologists could not have done bet-

ter, with such a great subject as animal life, than to begin with the simpler forms. But there can be nothing in common between man and worms, except that both have animal bodies. What we insist upon is that nothing bodily accounts for personality.

At the next stage in our ascent new heights appear which overtop anything yet encountered. So far man has been content to keep company with his physical senses, and when they grew weak to supply them with divers inventions of his to help them keep up with him. But now he proposes to leave them all behind, because they can only start him on his journey, something like a convenient cab which brings him to the railroad station. They cannot also be to him like the express train which is to transport him to some far-off destination in the great continent of knowledge. Ere long he will part with

the imagination also, because it is too weak a faculty now, since it can make its pictures only out of materials which the bodily senses furnish. A surer and more powerful agency than either the senses or the imagination is henceforth to carry him on, namely, his Understanding, that oldest and best name for the human Reason. The scientist walks by reason and not by sight. If he be a chemist he busies himself only with molecules, atoms, and ions, each one of these things being much larger than the other. I heard a professor of organic chemistry enthusiastically remark that he had met with such a huge molecule among the sugars, that if only he could multiply it twenty-five times he could then *see* it with a microscope! But no one has yet seen, or detected by any bodily sense whatever, a single molecule, still less an atom, and far less an ion which is a hundred thousand times smaller than

an atom. Then in the realm of pure physics all these things are also talked about until we finally hear about little else than the Ether, that wonderful something which not the most vivid imagination can connect with a bodily sense. Then when further progress in this direction slackens, the motor of mathematics is attached. Helmholtz regretted that Faraday, not being a mathematician like Clerk Maxwell, may have failed on that account to achieve still greater triumphs in physics than those which have made his name immortal. But where do we find ourselves now? Science can give only the same answer with Philosophy—we are in the realm of pure mind. Back of anything physical, and greater than anything physical, is the great fact of facts, Mind! And is not Mind to be found elsewhere in this Universe than on this little earth?

This last question suggests another

which is not easy to answer, and that is, why men naturally disbelieve in the existence of anything if it be not testified to directly by their bodily senses? Despite all evidences of the imperfections, if not of the untrustworthiness of those senses, most people will promptly reject whatever is not certified to by them, as if they constitute the sole foundations of belief. Reason may then protest, but she protests in vain.

All this is well illustrated by the history of one great word, which like many similar words we owe to that remarkable race which once appeared, as biologists would say, like a human sport in the small country of Greece. Such sports in Nature arise, no one knows why or how, and certainly it is not easy to account for the wonderful variety of intellectual gifts which the ancient Greeks possessed. Thus our English language testifies to the lusty,

vigor of our ancestors, for when we would speak or write strongly we rather use plain, short Anglo-Saxon words. But so soon as we wish to think clearly or scientifically, we have to ask the old Greeks, as the Romans did wholesale before us, to lend us their words, philosophy, theology, metaphysics, logic, theory, hypothesis, analysis, synthesis, music, and harmony; or physics, mathematics, arithmetic, circle, diameter, periphery, parallel, astronomy, geometry, geography, biology, physiology, and all other ologies; botany, chemistry, molecule, atom, ion, etc., etc. In fact our philosophy and our science would both come to a standstill if they had to speak only in English.

Now one splendid Greek word for whose irreparable loss the later Greeks were themselves to blame, was the word skepticism. The original Greek noun, a skeptic, meant a thoughtful, reflecting

man, an inquirer after facts or reasons, from the verb to look carefully around and to consider. Socrates claimed to be a skeptic, because he held his judgment in suspense until he could decide according to reasons. But in the course of barely three centuries this fine stock of men died out, and were succeeded by what our Western cattle-growers would call a breed of runts. Instead of the like of Socrates, Plato, and Aristotle, there arose a set called Pyrrhonists who made skepticism synonymous with its wretched counterfeit, Incredulity, and it has retained this ignoble meaning ever since, leaving the word in its original sense as dead and gone as the great-minded race of men who first made it. It was reserved for a man of another people, who when writing to Greeks thus defined the duty of a true skeptic,—Prove all things—and then hold fast to that which is good.

Now the contrasts between true skepticism and incredulity are these. Skepticism is deliberate, distrustful of appearances, grave, and candid. Incredulity needs no thought, but is peremptory and scornful, and not being reasonable it cannot be reasoned with. The one is a high and strong mental virtue, because it acknowledges no authority but that of reason. The other is a sign of mental debility, since the supposed verdict of the bodily senses is its all-sufficient authority. Because intrinsically they are of the same nature, both credulity and incredulity may be found in the same person. There are those who contemptuously brush aside the greatest achievements of medical science as they would a gnat, and then readily swallow a whole line of camels laden with the cures of so-called Christian Science. Incredulity was illustrated by a king of Siam who angrily ordered a traveller out of his pres-

ence because he said that in his country the water became so hard in winter that elephants could walk upon it. So when I stated to some Arabs that the earth revolved on its axis, they sneered as they pointed to the sea and asked if it would not all be spilled when the earth turned over. Once, while talking to a roomful of the naturally bright people of a town in Mt. Hermon about the achievements of Western civilization, I happened to tell a toothless old man present that in our country we had skilled persons who could make for him an entirely new set of teeth. Glancing round the room, I noticed some listeners stroking their beards in a fashion which I knew meant that I was telling a preposterous yarn. Fortunately I had with me an elderly Scotch friend who had a set of false teeth, and on explaining the situation to him, he forthwith opened his mouth and pulled the whole set out. The Arabs

jumped to their feet in fright, not sure but he might start to unscrew his head next, for had any of their venerated ancestors ever seen such an uncanny performance with teeth? They afterwards solemnly said that never would they have believed this if they had not seen it.

There is the essence of incredulity the world over, for a common English saying is, Only seeing is believing; in other words, we are to believe most in the reports of that sense which is more uniformly mistaken than in any other. The scientist, and particularly the biologist, is not sure about what he sees until he has otherwise tested it. Thus thirty-three distinct varieties of streptococci have been identified so far, and though in appearance they look exactly alike, it will make considerable difference to a man which one of them happens to get into him. Likewise all metazoa begin each as a micrococcus, and they then

all look alike both outside and in, though one is to grow into an ox, the other into a guinea pig, the other into an onion, and the other, it may be, into a professor of biology. Some powerful living things which we have spoken of have not yet been seen at all. Now it is not that scientists underrate the senses, but knowing their limitations they never allow them to contradict reason, however sense-born incredulity remains impatient of contradiction.

But the despotism of incredulity is most strikingly shown by the attitude of multitudes on the subject of the existence of mind. If only they could *see* mind, then they would be sure of its real existence. Every other evidence of mind, from an imposing cathedral to the equipments of a great university, leaves them still in doubt as to what mind is, including what their own minds are. May it not be simply an attribute of matter which we can see and

touch, such, for example, as brain matter? But modern medical science has deprived them even of this last visible and tangible mental stuff, as it proves that the brain no more itself thinks than the hand does, but, like the hand, is nothing else than the instrument of the invisible thinker. As with the hands and the feet, we have two brains, but only one of the two is that human brain which is the seat of all human mental faculty, while its fellow is nothing more than the brain of the primate Homo. It is the left brain in right-handed persons, and the right brain in the left-handed, which is the brain of a philosopher, of a statesman, of a poet, of an orator and what not, while its fellow knows not a word, nor can it recognize an object by any of the senses, nor conceive an idea. If brain matter as such is the source of mind, then both our brain hemispheres would be equally mental, when the truth

is that a man can feel just where his mind is in his head if he puts the proper hand to the other side of his skull. How it happens that virtually only half our brain matter is intelligent, and what that " how " proves as to ourselves, is discussed at length in the author's book, *Brain and Personality,* and therefore need not be further detailed here.

In conclusion we may say that it is quite natural for many persons to be perplexed at the opposite deductions of scientific men on the subject of the origin and nature of physical life. Some scientific authorities strongly, if not contemptuously, maintain that life is a purely chemico-physical phenomenon which some day will be so demonstrated. The conception that it is not so, but *sui generis,* they regard as a lingering superstitious myth. Others as firmly believe that nothing physico-chemical can possibly account for life, and

that there is no real evidence for such a supposition.

Now let no one imagine that this divergence of opinion can be removed by Evidence, because men are not constituted that way. Not by science are men born again, for however scientific they be, they remain the same as the rest of us, in that their opinions are settled for them, not by evidence, but by Preference, wherever preference has anything to do with a question.

Some may regard this statement as a humiliating arraignment of human reason, but whether humiliating or not, it is true. Opinions, the world over, have little connection with evidence, so that many of them instead have geographical boundaries. This of itself is enough, for reason as such has no more connection with geography than with meteorology. Opinions, on the other hand, come usually from the

interests engendered by circumstances, such as birthplace, inheritance, historical influences, party, or sect. One would not expect that a native of New England and a native of China would have many opinions in common. And so the great conflicts of history have not been decided by reasoning. One such conflict lately occurred in America, in which two branches of the same race, the one as well equipped with reasoning powers as the other, entertained such opposite opinions according to the side on which they happened to be born, of Mason and Dixon's geographical line, that finally their opinions were settled, not by arguments, but only by powder and ball.

Now it happens that on no subject in the world will opinions be found to be so determined ultimately by preference, as on this subject of the nature of physical life. Here likes and dislikes, and not evi-

dence, shape everything both in investigation and in discussion. The overpowering sway of Motive will be made plain by the following considerations.

As we have seen, the problem of the origin of physical life finally ends with the question, What are we ourselves? If only it ended before we became included in it, there would have been as little dispute as there is in a question about botany. But as it is, a now familiar answer to this question is, that we virtually are *things* which have come into existence by Evolution. What this means was explained by Huxley, and in brief is as follows: The doctrine of evolution assumes that in the primeval nebula from which this planet was evolved, everything potentially existed which in time would visibly belong to it. As by its own original properties it ultimately would give origin to seas and continents, so by them alone it

would give origin to life, whose successive forms would be evolved by the interaction of its own physical laws and forces. As evolution knows of no break or intervention, therefore we ourselves are its products also. Poets, philosophers, scientists, and all other human beings are samples of things which have thus come to be.

When the Darwinian theory was first promulgated, great was the enthusiasm of its advocates, because it seemed to give an account of the process of evolution fully in keeping with the fundamental postulates of the doctrine itself. We have seen how the astronomer, Sir Robert Ball, was enraptured with it on that account. We may remark, however, in passing, that the public has had several recent illustrations of the truth that astronomers, as such, are the last persons who can speak intelligently about life, because they deal with nothing living, but only with very distant

physical bodies, most of which are furiously burning. To speak at all about physical life, they first should walk on this earth like other people. But every such school of thought, whether astronomers, physicists, or biologists, have this bond of union between them, namely, the doctrine that we ourselves are things which have come into existence in essentially the same way as other things do.

No contradiction could be greater than that between this doctrine and the greatest truth which underlies this human world, as it can be expressed in these few words:

Things are not responsible, but persons are.

Every person, however insignificant he may seem to be, entails responsibility in one way or another. Thousands of poor immigrants are daily landed upon our shores, every one of whom then looks insignificant enough. And so they are quite

forgotten until we find that they have become voters, and count just the same as ourselves, so that we pay heavily in taxes and in misgovernment for our neglect of their education and due consideration. No person could have appeared more insignificant than the negro Dred Scott, when his case came before the Supreme Court of the United States. But when that court ruled that he should be rated only as a saleable thing, and not as a person, the most stable government in the world, whose money market felt no jar when either of three of its beloved presidents was murdered—that same government was shaken to its very foundations. History knows that the Dred Scott decision had more immediate effect in bringing on the terrible Civil War which followed it, than did any other one event.

But men instinctively feel that responsibility always circumscribes, if it does not

rob them of their personal independence. Every one wishes to be responsible to himself alone. It is only for the sake of his own convenience that he acknowledges the external authority of earthly governments or police, or will consider the opinions of his fellows. But within he will be free and think as he likes, and so act when possible. All this is befitting, for if a man is to be called to give a final account, that account should be of himself alone and of no one else. But most men prefer above all else the assurance that no such account is to be given. That assurance would be strong if only it could be demonstrated that men are nothing but things, or even machines which go as they are made to go. But to make their relief complete they should also be certain that there is nothing in the Universe but things.

There is no use, therefore, to continue this discussion, because it will be of no

avail when preference is so supremely dominant.

But that does not prevent us from stating our own preference, though from want of space we can refer to but a few out of many reasons for that preference.

In the first place, it looks incongruous to us for the advocate of this "thing" doctrine to put on the ermine of Science, and as Lord Chancellor take the seat of judgment. For he will lose both title and place with this first test case, which is that of one who may think of a person as a thing of molecules, atoms, and ions, only so long as what he is thinking about is the *other fellow*. But so soon as the same question is turned inwards and put to his own self, the conscious personality within answers with an emphatic, No! Let any one really try this on himself and he will see that he, and not molecules, is thinking, and that the consciousness of his

own personal existence is his certainty of certainties, which will remain unshaken by all warring theorists outside.

Some persons regard any allusion to mind as out of place in a scientific discussion, because science is concerned only with sensible phenomena, and mind can neither be tasted, smelt, seen, nor heard; it cannot be weighed, analyzed, resolved, precipitated, measured, or spectroscoped. But in this enumeration the tremendous testimony of the greatest of the senses is left out. Mind can be *felt,* so vividly that compared with it all mere phenomena are what this word originally meant, only appearances.

After all, the chief desire of the thing doctrine advocates is the assurance of a mindless, impersonal, and mechanically produced universe. At all hazards, therefore, it must be shown that the mind of the *person,* Man, is also of mechanical origin.

To admit that man's mind is not so, opens the way to the most far-reaching conclusions about the relations of mind to all existence. We have already shown how the person, Man, just because he is so, fills this world with his wonderful creations, none of which would exist but for his previously devising them. What would man create if, in place of his brief existence here, to him belonged that time which is unmeasured by the flight of years? But whose Image is now before us?

Equally as to his own being, it is plain that if he is to exist on this earth at all, he should have a physical body to correspond. It is difficult to imagine how it could be otherwise. If he must eat, he should have a stomach like other eaters, and likewise, all his bodily organs should be in keeping with those of the earthly animals of his class. And so we find it, particularly in the case of that bodily

organ, the brain, for man's brain and the chimpanzee's are so much alike that it takes an anatomist to tell the difference. But the same conscious personality within then says, I know that I am a real animal, but I also know that I am infinitely more than an animal, and there is the end of it.

Turning next to the subject of Evolution, to find what it really means, we perceive at once that instead of being an efficient cause, from the very nature of the case it is no cause at all. The running of a stream downhill is not the cause of its so running, for that is the earth's attraction of gravitation. And just so the long stream of the evolution of physical life is not caused by evolution. Science, therefore, is quite right in seeking for the cause of evolution, and despite frequent failures hitherto, she should keep on in this quest, for the longer she does so the less

will we hear of physical life being *caused* by evolution.

But in the course of this investigation Science will encounter a fact which is as much a fact as any other, and that is, that the human race, apparently because it is human, for no other species shows a trace of it, has always had a firm belief in the existence of a world unseen by human eye. This we meet not here and there, but everywhere. Incredulity is powerless against this belief. The lowest savage holds it so strongly that he is sure the most inanimate of objects has a living spirit behind it. But we have already mentioned a truth about sight which may indicate that this fancy of the savage has a physiological basis. The eye, by its imperfections as an instrument, has too often deceived him to have him believe that it sees all. We know that in this he is right, however mistaken he be as to the

objects which it does not see, because the eye in us falls so far short of our faculty of sight itself that we have to make up its deficiencies in all directions. And so with the other senses. In man there is no correspondence between faculty and instrument. Something more, and again more, is the persistent demand of the personality within, when comparing the boundless range of faculty with the vexatious littleness of range in the bodily senses. Nothing of the kind is found in other animals, for they are as content with their sense organs as the ass is with an ass's diet. They never think of going beyond their bodily senses. But in man such an equipment of faculties, with such poor provision for their exercise, is like finding on a canal boat engines which originally must have been meant for a steamer which would traverse the widest oceans.

What wonder, then, that this truth, coupled with that of the little speck of time allowed on this earth for the use of any faculty, should always have suggested another life than this to man? In that wider life who knows but that Reason's present subordinate relations to the Will, so that she cannot act except as the will allows, will be reversed, and the will act only as reason prompts. But even now, instead of asking the weak earthly imagination, let us ask Reason herself to tell us what the change inevitably would be if we entered another world with our faculties still the same that we have here, but with no limitations in their use. With sight, the farthest constellations would be seen, as no earthly eye is made to see them, just as they are in all their glory; likewise the lineaments of every face could be discerned, though in an assembly of the whole human race, for distance would make no

difference there as it does here. Again the ear could then hear, as no earthly ear can hear, the personal voice of every one there, whether in speech or song. Above all, the heart could then feel, and move to purpose and to design, as it never felt before.

These words have a familiar sound to us, because Paul used them on this same subject, but they will be lost upon him whose reasoning powers are paralyzed by imbecile Incredulity and perverse Will.

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